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EDITORIAL NOTE TO VOLUME VI, NUMBER 1

THIS number contains the Address given by the President at the Annual Meeting.

The series of biographical memoirs is continued by a contribution on William Lobb and John Jeffrey by Mr. W. D. Dallimore. The set of articles on Wood Preservation is completed by three by Dr. R. C. Fisher, Mr. J. Bryan, and Mr. W. G. Campbell. The series on Sitka Spruce will be continued in a future issue.

The results of the Forestry Commission research on 'The Form of Stem in Conifers' will be presented by Mr. James Macdonald in a series of articles, the first of which appears in this number.

The subject of forest soils and the mineral ion requirements of trees is one of first importance, and this issue contains three articles on this subject. The nutrition of fruit trees has been extensively studied during the last ten years in this country, particularly at Long Ashton, and we have invited Dr. T. Wallace, the deputy-director of that research station, to contribute an article summarizing the results of this research. It is hoped in this way to introduce foresters to this work, and to suggest lines for parallel investigations on forest trees. Mr. Aldrich-Blake contributes an article on 'The Influence of Nutrition on the Relative Root and Shoot Development of Forest-Tree Seedlings'. Mr. G. V. Jacks contributes 'A Study of some Yorkshire Moorland Soils'.

Many forest officers in the British Empire owe something to the stimulating teaching of Dr. Karl Philipp, of Baden. Some years ago we invited him to contribute an article on the Wedge System, the application of which in Baden has been one of the most interesting developments in post war German forestry. He was unable to undertake to do so, but in this number Mr. W. L. Marjoribanks contributes an article which has Dr. Philipp's approval.

EDITORIAL NOTE TO VOLUME VI, NUMBER 2

PROFESSOR PRIESTLEY has carried out researches into certain aspects of the physiology of trees during recent years, and made his results the subject of his presidential address to Section K, Botany, at the British Association Meeting, 1932. Professor Priestley has kindly rewritten his address from the forestry point of view, and this is published in this number.

In earlier numbers several articles were published on aspects of forestry in different European countries. This series is continued in this number by an article on 'The Forests of France', by M. Auguste Oudin.

Although short reports have appeared annually in the Press on Dutch Elm Disease, no comprehensive account of the disease in this country has yet appeared. Such an article by Mr. T. Peace, who has conducted the investigations on this disease in this country, is now published.

Mr. W. R. Day contributes a further article on certain aspects of frost damage to larch, and the second instalment of Mr. James Macdonald's studies on 'The Form of the Stem in Coniferous Trees' is included.

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ADDRESS TO THE SOCIETY¹

BY R. S. PEARSON

I HAVE had the honour of being the President of your Society during the last year, a year crowded with events, to which I propose to refer hereafter. Our Society is now firmly established and though numerically small, when compared with other societies interested in tree-growth and forest affairs, its personnel consists of a highly trained staff of forest officers, whose life-work is devoted to scientific forestry in every branch. Such a body of men can, and I feel certain will, do more to promote sound forest methods in the United Kingdom than any other organization. It therefore behoves us to hold together, and to do so necessitates meeting as often as possible to exchange ideas, compare notes, and get to know each other. Last year's Annual Meeting, which took place in Buckinghamshire, at which there was a very representative gathering of the Society, was an excellent example of the benefits which can be derived from such gatherings, and the Scottish members of the Society are to be congratulated on the way they rolled up in force, though the distance they had to travel to attend was very considerable. May I take this opportunity of urging on all our members the importance of such meetings and to ask them to stretch a point and make every endeavour to attend this year's Annual Meeting. I feel sure that they will not regret making such an effort, and that they will have a useful and enjoyable time.

I propose now to review briefly the more important events of the past year. The outstanding factor which has overshadowed forest policy and forest activities, not only at home, but all over the world, has been the economic blizzard, which reached a peak in June and July and still blows with unprecedented force. The effect of the economic stress has necessitated curtailment in planting activities both by the Forestry Commission and private owners, and a reduction in the pay of staff. Fortunately, it was not found necessary in the United Kingdom to make reductions in forest staff, except on a minor scale, though vacancies due to casualties have not been filled up. In some parts of the Empire matters have been more serious, and not only have cuts in general expenditure been called for, but definite reduction in the forest cadres has had to be made. The effect on research work has not been serious at home, the quite heavy reductions in general expenditure being allocated so as to avoid affecting investigations at present in progress and aiming more at curtailing the number of new investigations until more prosperous times. In India, on the other hand, it would appear that the original economy proposals would have so seriously crippled the work at the Forest Research Institute,

¹ Delivered at the Fifth Annual Meeting of the Society held at Edinburgh on 27 February 1932.

Dehra Dun, that much of the good work carried out in the past would have suffered very seriously. Fortunately, wiser councils eventually prevailed and sufficient funds voted to permit the work progressing on a reduced, though reasonable, scale. It has been pointed out on many occasions by eminent statesmen and foresters that without a fixed forest policy over a period of years the economic management of forests is not possible; and this applies not only to proper management and introduction of sound silvicultural systems, and to the suitable recruiting of trained forest officers, but also to the well-being of the population living in the vicinity of the forests, and to the wood industries dependent on a supply of timber for their maintenance. This axiomatic fact makes it the more necessary for us in this time of stress to see that we are not carried away by our momentary difficulties and that we apply our 'cuts' judiciously.

During last year two important forest conferences took place. In November 1931 a Conifer Conference was held under the auspices of the Royal Horticultural Society, when the Hon. H. D. McLaren, C.B.E., the President of the Society, delivered the opening address. A very fine exhibit of plants and branch specimens was a feature of the Conference, and at the same time the Council decided that a definite attempt should be made to reduce the names of the Coniferae to some sort of order. A line of work of importance and interest was to prepare a statement of height and girth measurements of the best-grown conifers in the British Isles, while a number of valuable papers were read on a variety of subjects by well-known authorities. In July 1931, in the grounds of the French Colonial Exhibition in Paris, an International Congress, dealing with silviculture and timber, was attended by over 400 members of many nationalities. A number of papers were read and discussed. The French authorities made a great feature of tropical timbers from their colonies, and deserve every credit for the effective way in which they were displayed. There can be little doubt that the French authorities, by concentrated marketing methods, supplemented by research, are expanding the markets for their colonial tropical hardwood timbers more rapidly than we are developing the huge resources of our Empire forests.

At the International Botanical Congress which took place at Cambridge in 1930, an idea was developed by Messrs. S. J. Record, L. Chalk, and B. J. Rendle to form an International Association of Wood Anatomists, and it was at the Paris Congress that a definite constitution for the Association was settled. This is an important step, and should lead to co-ordination in work and simplification in nomenclature and technique in dealing with the structure of timber.

The Committee set up in 1930 by the Secretary of State for the Colonies, in consultation with the Secretary of State for India and the Forestry Commissioners, under the Chairmanship of Sir James C. Irvine, C.B.E., LL.D., D.Sc., F.R.S., submitted its report during the year. The task set the Committee was necessarily a very difficult one. Space does not permit in a brief review of this nature of a discussion on the recommendations of the

Committee, though it is satisfactory to note that most of the important suggestions embodied in the memorandum submitted by the Council of our Society find place in their recommendations.

In the field of research satisfactory progress was made in the technique of raising birch and alder seedlings: experiments in peat soil were continued, and experiments to break up a pan-layer by means of a powerful tractor-driven plough proved successful. A survey, carried out to ascertain the extent to which the Dutch elm disease had spread, showed that though serious it was not spreading very rapidly. Similarly, a survey to determine the extent of the watermark disease in cricket-bat willow was undertaken, which showed that there exist several centres of attack, resulting in considerable losses to growers. In connexion with cricket-bat willow an extended investigation is under the consideration of the Forest Products Research Board, the aims being to determine the necessary qualities of the timber suitable for cricket-bats and to investigate the possibility of rendering timber of varieties of *Salix*, now used for second-grade bats, more suitable for the purpose.

Recently the Forestry Commissioners have appointed a Committee to advise on the more intensive utilization of home-grown timbers, whose endeavours will be watched with great interest by all interested in the welfare of British forestry. Research in timber has been steadily pushed on at the Princes Risborough laboratory. Of results of interest it may be noted that hardwoods react differently from softwoods when subjected to drying. For instance, in oak the reduction in total pentosans during drying is reflected in an increase of both cellulose and lignin components of the wood substance, whereas the depletion of pentosans in silver fir results in only slight additions of lignin. Results of importance have been obtained by reconditioning sawn timber which has collapsed, twisted, and warped during faulty seasoning. Certain species of timber become distorted to such a degree during seasoning that the sawn stock is greatly reduced in value. As instances may be mentioned Dutch and common elm, both species being liable to collapse and warp; ash which is liable to warp when cut through and through; certain Eucalypts, such as Tasmanian oak, &c. A treatment has been evolved by which the distortion in the timber can be completely taken out, or nearly so, and remain in shape. This can be achieved by subjecting the timber to a temperature of 100° C. in completely saturated air for 4 to 5 hours, and then allowing it to cool down slowly. It is thought that this may be the solution leading to the more profitable utilization of elm and other refractory species of timber.

The year has been marked by an unprecedented effort to introduce Empire-grown timbers, which naturally include home-grown varieties. The concentrated efforts of the Empire Marketing Board, the Forest Products Research Laboratory, the Government Departments, and especially H.M. Office of Works, the Post and Telegraph Department, the London County Council, and other similar bodies, and notably many individual timber merchants, have certainly obtained results worthy of the effort. The will to 'Buy British' is such that every opportunity should be taken to grasp this occasion to develop the

markets in home-grown and overseas Empire timbers, as it is not likely that such a chance will again come our way within our lifetime.

In conclusion I should like to express my gratitude to the members of the Council, whose work to further the well-being of our Society has been unfailing. Without the never-failing assistance and sound advice of our immediate Past-President, Mr. J. D. Sutherland, and our ever-helpful Secretary and Treasurer, Mr. R. Angus Galloway, I should have felt very lost. I hope that other members of the Council will forgive me if I specially single out Dr. H. M. Steven and Major J. R. Cosgrove for a special word of thanks, the former in connexion with his work as Editor of our Journal, and the latter in connexion with the arrangements for the summer meeting.

WILLIAM LOBB AND JOHN JEFFREY

BY W. DALLIMORE

WILLIAM LOBB was the first of many travellers and collectors sent to various parts of the world by Messrs. Veitch, originally of Exeter and afterwards of King's Road, Chelsea, between the years 1840 and 1905 when, with the successful conclusion of Mr. E. H. Wilson's second visit to China, Messrs. Veitch ceased to identify themselves with direct exploration. Lobb was a native of eastern Cornwall, and in early life was employed by Mr. James Veitch in his nursery at Exeter. He then spent about 3 years as gardener to Mr. Stephen Davey of Redruth, but he possessed a very definite desire for travel, and as he had deeply impressed Mr. Veitch with his powers of observation, resourcefulness, and attention to detail, he was offered an opportunity of proceeding to South America for the purpose of collecting plants. He sailed from Plymouth for Rio de Janeiro in 1840, and his early introductions from Brazil included numerous orchids. After collecting in Brazil he proceeded to Chile and the Chilian Andes, finally arriving in the forests of *Araucaria araucana* (*imbricata*) where he was instrumental in collecting sufficient seeds to remove this species from the position of an exceedingly rare tree to one available for every garden. This was perhaps the most important hardy tree of which he collected seeds during this tour, his activities being more concerned with plants suitable for cultivation in glass-houses.

He returned to England in 1844, renewed his engagement, and sailed again for Brazil in 1845. He made his way to southern Chile, and there collected seeds or plants of numerous decorative trees and shrubs that are seen at their best in Cornish gardens or in other places where similar climatic conditions prevail. Amongst other plants he sent home *Fitzroya patagonica*, *Podocarpus nubigena*, *Libocedrus tetragona*, *Embothrium coccineum*, *Desfontainia spinosa*, *Escallonia macrantha*, *Berberis Darwinii*, *Lapageria rosea*, &c. He returned from this journey in 1848, and in 1849 he was sent to California and Oregon to collect seeds of the various conifers introduced by Douglas at an earlier date, but which were very rare in cultivation. He had, of course, to look out for new species in addition to collecting seeds of those already known. It is from this time to the completion of his connexion with the Veitchian firm in 1857 that Lobb's name is most intimately connected with forestry and arboriculture. Messrs. Veitch gave an excellent account of his life and work in *Hortus Veitchii* in 1906, pp. 37-40, and from those pages the following notes are extracted.

'The wonderful Conifers discovered by Douglas in California and Oregon were then still very scarce in England, and young plants of most of the species could scarcely be bought: it was therefore decided that Lobb should proceed

to California with a view of obtaining seeds of all the most important kinds known, and, if possible, discover others.

‘He landed at San Francisco in the summer of 1849, and at once made arrangements for exploring Southern California.

‘One of the first fruits of the expedition was the successful introduction of *Abies bracteata*.

‘During the years 1850–1851 consignments were sent home of cones and seeds of *Pinus radiata*, *P. muricata*, *P. Sabiniana*, *P. Coulteri* and *P. tuberculata*; and also of many shrubs and flowering plants, quite new to British gardens.

‘In the autumn of 1851 his operations were pushed further north, and cones and seeds collected of the Redwood (*Sequoia sempervirens*), *Pinus Lambertiana*, *P. monticola*, and others.

‘In 1852 Lobb made an excursion to the Columbia River and Oregon, where he succeeded in obtaining seeds of *Abietia* (*Pseudotsuga*) *Douglasii* and *Abies nobilis*, still rare at that time in England, and the beautiful *Thuja* provisionally named after him.

‘Returning through North California, Lobb collected seeds of *Abies grandis*, *A. magnifica*, which he sent home under the name of *A. amabilis*, believing it to be the *A. amabilis* of Douglas, *A. concolor* Lowiana, the first received in England of that fine fir, *Juniperus californica*, and of *Pinus ponderosa*.

‘In 1853 the Sierra Nevada was explored, the traveller tempted by the reports of the discovery of trees of extraordinary magnitude, which he had the good fortune to find, and to secure the first cones and seeds of *Sequoia gigantea* received in England.

‘Lobb brought these home at the end of the year, and with them two living plants, afterwards planted out at Exeter, where they survived but three or four years, nor was there at any time much hope of their living.

‘Lobb returned to California in the autumn of 1854, and from that time up to the end of 1856 continued to send home consignments of plants and seeds.

‘In 1857 his engagement with Mr. Veitch terminated. He remained, however, in California, and sent collections of seeds to England from time to time. In 1863, seized with paralysis, Lobb lost the use of his limbs; he died at San Francisco in the autumn of the same year, and was buried in Lone Mountain Cemetery.’

Unfortunately, Lobb’s name is not definitely connected with any well-known hardy tree. There is certainly a *Thuja Lobbii*, but that name is actually a synonym of *T. plicata*. *Cryptomeria japonica* var. *Lobbii* commemorates Thomas Lobb.

William Lobb’s brother, Thomas, also collected for the firm of Veitch from 1843 to 1860, but as his work was largely in the tropics his name is better known as a collector of orchids, ferns, nepenthes, palms, &c., than of hardy trees.

John Jeffrey’s collecting activities were, so far as is known, limited to the years 1851, 1852, and 1853. The first that appears to be known of him was a young gardener in Fife, from whence he went to the Royal Botanic Garden

Edinburgh, to improve his knowledge of plants. His outstanding ability attracted the attention of Professor J. H. Balfour and Mr. Macnab, the higher officials of the gardens, and when a man was asked for to follow up the earlier work of David Douglas in western North America, Jeffrey was appointed. The expedition was made possible through a number of patrons of botanical science, horticulture, and arboriculture uniting to form an 'Oregon Botanical Association'. The first meeting appears to have been held on 22 November 1849 at the Botanical Garden, Edinburgh, under the chairmanship of Professor J. H. Balfour, and a decision was arrived at 'to send to western North America a botanist, who should collect the seeds of trees, shrubs and other plants suitable for horticultural purposes, in the region traversed by David Douglas, to complete his researches, and to extend them into those parts of the country not fully explored by him'.¹ Jeffrey sailed from London in June 1850 for Hudson Bay, and on arrival he accompanied the Hudson Bay Company's dispatch brigade across the continent in the following winter. On 7 April 1851 Jeffrey wrote to Professor Balfour from Jasper House in the British Rocky Mountains informing him of his travels since leaving York Factory on Hudson Bay on 20 August 1850. From Jasper House he proceeded by devious ways to Washington where he arrived on 13 May 1851. From there he appears to have travelled to Vancouver Island where he spent the winter of 1851-2. Towards the end of April he left Vancouver Island, travelling widely in Washington and northern California, eventually, in 1853, passing on to Sacramento Valley and San Francisco Bay.

As might be expected, from the extent of his travels and the difficulties of communication 80 years ago, news of the traveller and consignments of seeds and plants reached Scotland at very infrequent intervals, and from the tone of the following note which appeared in the *Gardener's Chronicle* for 28 August 1852, p. 551, some anxiety had been felt. 'Scotch Expedition to Oregon:—We learn that at last a box has arrived from Mr. Jeffrey, the collector to the Edinburgh Association. Upon opening the box, one or two live specimens of the curious *Lewisia rediviva* appeared, and a great many fine things. The distribution will occupy much time. Dr. Greville, who is not a subscriber, has kindly undertaken the very laborious task.' On the whole, the subscribers appear to have been satisfied with the results of the 1851 and 1852 collections, but according to the *Pinetum Britannicum* (under the description of *Pinus Jeffreyi*), i. pp. 45-6, 1853, was not a very successful year. The author says: 'In the second year (1852) Jeffrey went further south and sent home seeds of *Picea* (*Abies*) *nobilis*, *P. (A.) amabilis*, *P. (A.) grandis*, *Pinus tuberculata*, *Pinus contorta*, besides the very interesting *P. Balfouriana* and *Thuja Craigiana* (*Libocedrus decurrens*). His collections in the second year, however, scarcely kept pace with those of his first year; and in the third year a very marked falling off in the consignments accompanied by a total cessation of correspondence led to his engagement being brought to a termination. What became of Jeffreys afterwards is not known.'

¹ Colville, John Jeffrey, *Proceedings of the Biological Society of Washington*, March 1897.

How far this is correct is difficult to say, for although his engagement by the Oregon Botanical Association was for three years, in an account of the Botanical Expedition to Oregon by the Secretary, Andrew Murray, published in 1853, the Committee had considered ways and means of procuring the necessary sum of money to retain his services for another year, the following paragraph making that quite clear:

'The object appears to the Committee so desirable, that they have to suggest to the subscribers the propriety of forming an Association for the year from November 1853 to November 1854. If sufficient funds are subscribed, they are enabled to secure Mr. Jeffrey's services.'

However, no one appears to have been able to get into touch with Jeffrey, and probably Coville is correct when he terminates the article previously cited, p. 60, in the following words: 'No further information about Jeffrey appears to have reached Edinburgh, but to those who know the terrible chance taken by a man attempting a trip to Yuma in the fifties alone, there is little doubt that he perished of thirst upon the Colorado Desert.' In the search for Jeffrey a suggestion had been made that he set out for Fort Yuma.

Jeffrey's name has been commemorated in *Pinus Jeffreyi*, a pine closely related to and usually accepted as a variety of *Pinus ponderosa*, the yellow pine of western North America.

The chief trees collected by Jeffrey were: *Abies nobilis*, *A. Lowiana*, *Pinus Balfouriana*, *P. contorta*, *P. Banksiana*, *P. ponderosa*, *P. ponderosa* var. *Jeffreyi*, *P. attenuata* (*tuberculata*), *P. contorta* var. *latifolia* (*Murrayana*), *P. flexilis*, *P. Lambertiana*, *P. albicaulis*, *P. mitis*, *Pseudotsuga taxifolia* (*Douglasii*), *Picea sitchensis*, *Tsuga Mertensiana* (*Pattoniana*), *Libocedrus decurrens*, *Tsuga heterophylla*, *Thuja plicata*, *Castanopsis chrysophylla*, *Quercus agrifolia* vars., *Acer circinatum*?

It will thus be seen that William Lobb and John Jeffrey were commissioned at practically the same time by different patrons to carry out identical work. Lobb appears to have had the better opportunities, for not only had he had previous experience in travel and in plant and seed collecting, but he probably had an advantage by working from San Francisco northwards, instead of in the opposite direction as was done by Jeffrey.

THE NUTRITION OF WOODY PLANTS

(WITH SPECIAL REFERENCE TO CULTIVATED FRUIT PLANTS)

BY T. WALLACE

(Deputy-Director, Long Ashton Research Station, University of Bristol)

INTRODUCTION

THE ultimate practical object in nutritional investigations of fruit plants is to discover methods of controlling the growth processes which determine the yields and qualities of the fruits borne by the various types of plants utilized in fruit-growing. The fruit tree has no value to the fruit-grower other than as a medium for producing fruit, hence the value of any given tree is measured in terms of the value of the crops which it is capable of yielding. For this reason the general outlook of the research worker on nutritional problems of fruit trees must differ somewhat from that of the forestry expert whose main object is timber production, but nevertheless the problems in the two instances necessarily provide points of common scientific interest. Thus, although in one case the major practical object is fruit and in the other it is timber, the fundamental scientific problems involved relate to the growth processes of the trees.

The production of crops of fruits with definite qualities, and of timber with specific properties, are merely expressions of the particular nutritional conditions of the various trees concerned, and to understand either it is essential to study the many and varied problems relating to general nutritional processes. The common problem may be stated as 'The growth responses of woody plants to various environmental conditions over relatively long periods of years'.

The more important broad differences which occur in the two cases may be stated as follows:

Fruit plants have been evolved primarily for qualities relating to fruitfulness, whereas forest trees have been selected for timber production. In the former instance, crops are removed periodically during the growth period, and in the latter products are not usually obtained during the growth periods of the trees.

Fruit plants in general occupy more favourable growth sites than forest trees: soil conditions are generally selected as being especially favourable to tree growth. In the case of forest sites the land utilized is usually of the type regarded as of low value for agricultural crops, and the situations are frequently such that the trees are exposed to very unfavourable climatic conditions.

The systems of management of fruit plants are much more intensive than those applied to forest trees: cultivation is carefully adjusted to meet particular requirements, and is varied from time to time; manuring is regularly practised, often at a high level; pruning is systematically carried out and frequently in

a most detailed way; and pests and diseases are combated by most elaborate seasonal spraying programmes.

The management applied to forest trees must necessarily be much simpler, and thus fluctuations in nutritional conditions in forest trees over the growth period, due to management factors, are likely to be less than those which occur in fruit trees over the life-history of a well-managed fruit plantation.

In both instances the nutritional conditions which exist within the trees are the resultant of the intrinsic properties of the materials planted and the environmental conditions which are operative on the plants over the growth histories.

In the case of fruit plants the more important factors which determine the nutritional conditions at any time may be grouped as follows:

- (a) Materials—including the classes of fruit, varieties, rootstocks in the case of the majorities of tree fruits, and the age of the plant.
- (b) Environmental factors—these may be divided into two subgroups.
 1. Natural conditions—including the climatic factors of rainfall, temperature, sunshine, &c.; soil factors—embracing chemical, physical, and biological properties; parasitic organisms—pests, fungi, &c.
 2. Management factors. These include soil treatment—cultural operations and manuring; control of pests, fungal and bacterial organisms, &c.; manual operations on the tree, such as branch-pruning, fruit-thinning, bark-ringing, &c.

The effects which may result in particular instances from these factors may be illustrated by the following facts which have been elucidated during the course of investigations at Long Ashton.

Plums and black currants as classes yield the best results under 'high' nitrogen conditions; apples, gooseberries, and red currants usually fail under 'low' potassium feeding; varieties and rootstocks exhibit marked differences in resistance to unfavourable nutritional conditions; old trees require 'high' nitrogen feeding; high rainfall during the growing season produces effects similar to high nitrogen feeding, and dry soil conditions tend to counteract high rainfall effects; grass systems of culture induce low nitrogen conditions within the trees, and tend to reduce effects due to low soil potassium; pruning may produce growth responses similar to manurial effects; management factors may greatly alter disease problems by affecting the susceptibility of the plant or by ensuring freedom from attacks of pests or organisms.

The foregoing statements will suffice to show the similarities and differences which are likely to occur in investigating nutritional problems relating to fruit trees and forest trees.

The present paper has been written primarily with the view of bringing to the notice of workers interested in problems of the nutrition of forest trees the results of nutritional investigations on fruit trees which have been carried out by the writer at Long Ashton Research Station since 1920. In order that

readers may also become acquainted with other investigations in the subject, a brief outline of previous and contemporary work is also included.

HISTORICAL

Previous to 1920, by far the greatest proportion of investigations relating to the nutrition of fruit trees had been carried out in the U.S.A. In this country the only extensive experiments up to that time were those of Bedford and Pickering at Woburn (7), and of Dyer and Shrivell at Hadlow, Kent (10). In European countries no sustained investigations appear to have been conducted prior to the above date, although numerous references appear in the literature of minor investigations, and especially in connexion with pathological conditions arising from defective nutrition. (See references in papers 45, 48, 51.)

The older experiments both in the U.S.A. and in this country consisted almost wholly of field experiments, modelled after the pattern of the classical experiments on agricultural crops instituted at Rothamsted by Lawes and Gilbert, in which it was usual to test the effects of various manurial treatments, such as dressings of dung, complete fertilizers containing nitrogen, phosphorus, and potassium and complete fertilizers less nitrogen, phosphorus, and potassium respectively against control treatments where manurial dressings were completely withheld. In the U.S.A., after 30 years of experimenting along these lines, it was realized that the results obtained were extremely small in proportion to the time, energy, and expense involved, and it became generally accepted that the field experiment method, as previously used, was not likely to lead to the acquisition of much knowledge of the nutritional problems of fruit trees. The more important of these older investigations have been previously discussed by the writer (40), hence in the present instance it will suffice to draw attention to the salient points which appeared to emerge from the work.

W. H. Alderman (2), in a paper entitled 'The Status of Orchard Fertilization Experimentation' delivered before the American Society for Horticultural Science in 1919, summarized the results obtained during the previous 30 years, and stressed the inadequacy of the field experiment method as practised to throw light on the problems of fruit-tree nutrition. He stated the position reached as follows: 'This seems to be a suitable occasion to pause and consider the work that has been accomplished to date. Within the past two years a number of well conducted experiments extending over long terms of years have matured, and the results been made public. So much has been written on the subject that it is a bit difficult to summarise the case, since the evidence does not all point in the same direction. It is somewhat simpler if we first confine ourselves to the points over which there is seemingly no contention.

'1st. There are apparently a great many orchards growing upon a wide variety of soils that will not respond economically to the application of any form of commercial fertilizer, nor of manure. This fact is well established by the work in New York, New Hampshire, Maine, West Virginia, and other states.

- '2nd. Orchards are much more likely to respond favourably if they are given sod mulch treatment than if kept under cultivation. A comparison of the work in the above mentioned States with that in Massachusetts and Ohio, furnish interesting evidence upon this point, as does also the work in Pennsylvania where the three sod orchards displayed considerably greater gains than the three under cultivation.
- '3rd. Orchards under starvation conditions usually give a ready response to fertilisation when other treatments (culture, pruning, spraying, etc.) remain unaltered. This is well demonstrated by some of the Ohio, Oregon, and West Virginia experiments.
- '4th. Nitrogen in a readily available form seems to be the only element of plant food that is uniformly a factor in the favourable responses—when such are secured.

'These four points, apparently, are about the only outstanding, uncontested results of our orchard fertiliser experiments, conducted over a period of thirty years or more by twenty-eight different experiment stations. This information is of no small value to the orchard industry, and has been well worth working for, but the investigator who is seeking to understand the "how" and "why" of the reactions finds only disappointment. There have been those among us who have thought and talked of principles that underlie orchard fertilisation, but so far no principles have been formulated which are capable of application. There are others—probably the majority—who have maintained that orchard fertilisation cannot be reduced to general principles having a wide application. So far this group has not been disappointed.'

Two experimental centres were utilized at Woburn (7), one on a heavy soil at Ridgmont and the other on a light sandy soil at Millbrook. At Ridgmont no significant effects, either on the growth or fruiting of apple trees were obtained from dung or fertilizers, although on the same plots bush fruits, nursery stock, and vegetables responded to the treatments. Pickering accepted this result as a likely one for fairly fertile soils of the Ridgmont class. On the light sandy soil at Millbrook apple trees and gooseberries responded to dressings of dung and fertilizers, provided the latter contained potash. At Hadlow (10) the outstanding result was the action of potash fertilizers for all classes of fruits, although the soil was of heavy texture.

Since 1920 nutritional problems on fruit trees have been approached from a new angle in the U.S.A., chiefly owing to the comparative failure of the previous work, and to the stimulating carbohydrate/nitrogen theory of Kraus and Kraybill (26). This hypothesis has served to focus attention on the inter-related conditions of growth and fruitfulness, and attempts have been made to interpret nutritional conditions in terms of carbohydrate/nitrogen ratio. Following these lines attempts have been made to analyse the chemical factors associated with shoot-growth responses, fruitfulness and unfruitful conditions, blossom-bud formation, fruit set and biennial bearing, and no field experiment is now considered complete without parallel chemical and physiological investigations. Published papers relating to these investigations are extremely

numerous, and for an introduction to the literature the following books and journals should be consulted (3, 8, 11).

A second phase of modern field experiment work requires mention, namely, the application of statistical methods, and reference to the above-mentioned publications will provide numerous examples of typical studies of this kind.

These further investigations have continued to demonstrate the importance of nitrogen for fruit trees under U.S.A. conditions. There is still no clear evidence that phosphatic manuring produces direct responses in fruit trees, though in several instances it has been shown that indirect effects may follow from the application of phosphates by stimulating the growth of leguminous cover-crops (5). Potash has only been shown to be a problem in one or two isolated instances, the most important being a case of prunes, studied by Hoagland (21) and his associates in California, a further instance being one under investigation by Shaw in New Hampshire (35). Of other field problems, certain relating to pathological conditions require mention, viz. lime-induced chlorosis associated with iron deficiency (23, 28), mottle leaf of citrus (16, 17, 18, 24), boron toxicity (25), and rosette of apples and pecans (29, 30). The investigations of Veihmeyer (38, 39) and his associates, relating to problems of soil moisture supply and irrigation practice in connexion with fruit-tree nutrition, also form important contributions.

Haas (15, 33) and his co-workers have been pioneers of intensive laboratory and pot studies on citrus and other trees in the U.S.A., and have made important advances in the knowledge of the action of mineral elements in tree nutrition.

In this country, in addition to the nutritional work at Long Ashton, several manurial experiments on fruit trees have been carried out at East Malling Research Station (4, 13, 14, 20) during recent years in which the importance of potash for apple-trees, and the necessity for considering the particular requirements of varieties and rootstocks in nutritional investigations, have been clearly established. At this centre the technique of manurial experiments has been closely studied and new experiments are being developed in accordance with the most recent statistical requirements (22).

No outstanding developments have resulted from recent nutritional work on the Continent, but it appears certain from the isolated results (12, 31, 32, 34, 36, 39a) which continue to be obtained that problems associated with potash deficiency will be found of outstanding importance, as has been the general experience in practically every fruit-growing area in this country.

LONG ASHTON INVESTIGATIONS

In the investigations carried out at Long Ashton an attempt has been made to study nutritional problems by laboratory and pot-culture methods in addition to conducting comprehensive field investigations. The main subjects of study may be grouped under the following heads:

- (a) Effects of deficiencies of the major 'essential' elements of nutrition.
- (b) The diagnosis of nutritional problems in the field.

- (c) Materials, soil conditions, and management factors in relation to nutritional conditions.
- (d) The correlation of nutritional conditions and manurial responses to chemical composition of fruit plants.
- (e) Pathological conditions—Leaf scorch and chlorosis.
- (f) Factors determining fruit quality.

Effects of deficiencies of the major 'essential' elements of nutrition.

Deficiency effects have been studied in great detail for the elements nitrogen, potassium, phosphorus, calcium, and magnesium, and to a less extent for sulphur and iron. In the cases of the former group and of sulphur the investigations have been pursued chiefly by means of sand cultures, using chemical solutions as the sole source of supply of the various elements (40, 41, 42). The observations relating to nitrogen and potassium (42, 43-7, 50, 54) have also been partly gained in field studies in instances where deficiencies of the elements have been proved and, in the case of iron deficiency (48, 49, 51), the whole of the facts have been elucidated in connexion with deficiencies of this element in specific cases of lime-induced chlorosis, which subject is discussed in detail in a later section.

The features on which data have generally been collected have been as follows: (1) times of opening of leaf- and blossom-buds; (2) blossom characters; (3) foliage characters throughout the season; (4) shoot growth; (5) defoliation phenomena—relation to time, method and tints developed; (6) condition of barks; (7) yields and characters of fruits; (8) root systems.

The following is a summary of the main deficiency effects which have been observed. For further details and for an account of technique employed in carrying out sand-culture experiments the reader is referred to the following papers (40-2, 54).

Nitrogen deficiency. In pot experiments the omission of nitrogen from nutrient solutions produces deleterious effects more quickly than the omission of any other of the major essential elements, and with young trees under this treatment the growth made during the first season is frequently similar to others receiving a complete starvation diet of 'water only'. The times of opening of blossom- and leaf-buds are delayed, blossom formation is drastically reduced owing to the death of lateral buds, and the flowers are very weak. Foliage is relatively scanty, and after a season or two of the treatment the trees usually only carry foliage at the tips of shoots, thus presenting a characteristic 'bare-wood' appearance. The leaves are relatively small and yellowish green in colour and often develop orange or reddish tints towards the end of the season. Small reddish brown spots may appear on the leaves. Shoot growth is drastically reduced, and after a short period of treatment the trees fail to make appreciable shoot growth. Defoliation is premature and the tints at defoliation time are reddish yellow. The barks become pale brown in colour. Fruiting is quickly reduced to a negligible amount owing to the non-development of lateral buds. Fruits are small, often highly coloured or of chlorotic appearance,

relatively hard in texture, and with high $\frac{\text{sugar}}{\text{nitrogen}}$ ratio. They possess excellent storage qualities both in ordinary and low temperature stores. The root systems are small and in proportion to the amount of shoot growth made, and are composed mainly of fine fibrous rootlets. Nitrogen starvation is of frequent occurrence under grass systems of cultivation and is easily remedied in such cases by cultivation. Trees in low nitrogen conditions react readily to applications of nitrogenous fertilizers.

Potassium deficiency. In pot experiments the effects of potassium deficiency are less drastic than those due to nitrogen omission, but starvation from the former element is a much more serious problem in the field. In sand-culture experiments omission of potassium usually advances the opening of blossom- and leaf-buds, and the blossoms formed are generally strong and normal in appearance. The number of blossom-buds is not drastically decreased as in the case of nitrogen starvation, and indeed may show some increase over completely fed trees, due to the fact that potassium deficiency leads to die-back of shoots, and abnormal development of fruit-buds follows. This condition is often very marked in cases in the field where practically every bud may be a fruit-bud.

During the early part of the season the foliage characters are usually quite normal in appearance, but later, generally from the beginning of June, the special symptoms of the shortage of the element become visible. The colour of the leaves at this stage is often bluish green and there may be slight chlorosis near the margins and between the veins. In some varieties of plum the chlorotic symptoms are strongly marked. In gooseberries the leaves at this stage may show purple tints, but these disappear later. There is often a tendency for the edges of the leaves to curl towards the under surfaces, but, in the case of certain plums, the curling effect is in the reverse direction. The leaf margins finally become brown or grey, following the death of cells in these areas, and have the appearance of having been scorched by fire. This condition is commonly known to fruit-growers as Leaf Scorch and is usually well marked both in pot experiments and in the field by the end of July. This marginal browning may extend inwards between the veins, practically to the midrib, this being usual in the case of the raspberry. Leaf scorch becomes most marked in hot dry summers. In advanced stages of potassium deficiency leaf size is considerably decreased and scorching is less well developed.

In pot experiments shoot growth may be only very slightly affected in the early stages, but eventually it is greatly curtailed and shoots tend to die back, and even whole branches may be thus affected. These latter symptoms are common in the field.

Defoliation from potassium deficiency in the field occurs prematurely, following the development of marginal leaf scorch, and this often happens in pot experiments. Under the latter conditions, however, defoliation may occur later than in the case of 'complete nutrient' trees, the leaves appearing to hang on in a tenacious way. Where defoliation is extremely premature a second

crop of leaves may be developed. During defoliation the colour of the leaves usually turns direct from green to brown, and high tints are generally absent. The method of defoliation is unusual, frequently progressing in the direction from the tips to the bases of the shoots so that the oldest leaves are retained latest. The colour of the barks may be slightly paler than normal.

Fruit yields are greatly reduced in spite of the large number of fruit-buds carried, since, although the buds form blossoms and these set, the fruits formed are very liable to drop and the crop consists almost wholly of culls. After harvest the fruits remain of dull immature appearance; they are sub-acid, often sweet or woody and flavourless, shrivel greatly in store, and frequently are excellent keepers in ordinary temperature stores, but break down prematurely in low temperature stores. Root systems in the field are usually poorly developed, and badly scorched trees frequently feel quite loose when shaken.

Two important practical points relating to potassium deficiency which require mention have emerged from both pot and field experiments, namely, the deficiency appears to promote physiological drought within fruit trees when the environmental conditions are conducive to drying out, and it must usually be considered in relation to the available nitrogen supply to the plants where it occurs. Potassium deficiency is the most serious deficiency 'disease' of fruit-trees in this country, and in the past has been of very frequent occurrence. The field problem is discussed more fully later.

Phosphorus deficiency. The effects of phosphorus starvation of fruit trees in sand cultures after two or three seasons are as severe as, or more severe than, those resulting from nitrogen deficiency, and the features exhibited in the two cases show many points of similarity.

The times of opening of blossom- and leaf-buds are appreciably delayed, and in extreme cases are delayed beyond the times when these occur in comparable trees receiving total starvation diets, i.e. water only. Blossom formation is much reduced, due to the death of lateral buds, and the blossoms are very weak. The foliage exhibits very distinctive characters. The amount is very small, and eventually the only leaves developed are the terminal rosettes. Leaf size is much reduced. It will be evident that the above characters are similar to those due to nitrogen deficiency. In the early spring the leaves are fairly normal in colour, though of rather dull appearance, but they soon become very dull and eventually exhibit characteristic purple and bronzed tints over their entire surfaces, the tinting often being accompanied by the presence of brownish spots, which are pronounced in the case of the black currant. After bronzing, areas of the leaves become dried out.

Trees undergoing phosphorus deficient treatment frequently make excellent growth during the first season, and show little effect from the deficiency—apparently because of the utilization of reserves—but from the second season shoot growth is generally as severely restricted as from nitrogen starvation, and this condition continues from this point. Defoliation is greatly advanced; it may occur in early June and previous to defoliation taking place in trees receiving 'water only' treatment. The barks of the trees are slightly paler than

normal in colour. The yield of fruit is greatly affected and is similar to that which results from nitrogen deficiency, in both cases the reduction being due to dying out of the lateral buds. The colour of the fruits is dull and unattractive, with a suggestion of the bronzing which develops so markedly on the leaves. Unlike low nitrogen fruits, those from phosphorus starvation lack firmness and have no desirable commercial qualities. The root systems are small in proportion to the tops. They often lack fibre and show a characteristic brown colour.

Although phosphorus deficiency in sand cultures produces such drastic effects on fruit trees, no case of proved phosphorus starvation has been observed by us in the field, although cases have been examined on soils which fail to grow pasture plants healthily due to deficiency of the element. It thus appears that the various fruit plants with which we are concerned are good phosphorus feeders.

Calcium deficiency. This treatment has not been observed to produce any effects on the times of opening of blossom- or leaf-buds, and the blossoms which have been developed have always been normal in character. In sand cultures trees receiving diets deficient in calcium usually carry luxuriant foliage in the early stages, the leaves being definitely larger than those in 'complete nutrient' series. This effect is possibly due to 'high' potassium which results, and it has been shown that the large leaves so produced are relatively resistant to water loss under conditions conducive to rapid drying. At a later stage in the treatment leaf size is more normal, and the leaves may show break-down symptoms. In the case of the apple these take the form of patches of dead tissue either near the centres of the leaves or near the margins and, in the latter cases, the brown patches have a reticulated appearance. Similar symptoms result from magnesium deficiency, though in this latter instance the extent of the break-down is much more serious. With plants other than the apple we have not yet been able to produce any consistent and distinctive foliage characters from lack of calcium. In the large leaf stage calcium deficiency is associated with increased shoot growth, and, in our experiments, even after three or four seasons of treatment we have not so far succeeded in effecting significant reductions in shoot growth. Defoliation characters do not show any distinctive features, and the barks are of normal appearance. Nor have distinctive points been observed with regard to fruit characters or root systems. No instance due to calcium deficiency has been observed in the field.

Magnesium deficiency. The times of opening of blossom- and leaf-buds have not been affected by omitting magnesium from the diets of various sorts of trees, and the character of the blossom has always been normal. Very striking effects are produced on the foliage of all fruit plants from a very early stage. In the first stages of magnesium starvation leaf size is inclined to be increased, and usually remains of at least normal size over two or three seasons. In advanced cases, however, the leaves become very dwarfed.

Each class of plant appears to develop a specific type of break-down symptom, and it is necessary to experiment with each to determine the characteristic

features. In the case of the apple the usual symptom is the death of a relatively large patch of tissue near the centre of the leaf around the midrib, and this condition we have termed 'blotch'; but the patches may occur in a haphazard manner on any portion of the leaf, and in some varieties are frequently developed around the margins (*c.v.* calcium deficiency). In the later stages of the deficiency the green colour of the leaf may be slightly pale. In the case of the black currant the central portion of the leaf turns purple, and this coloration develops over practically the whole of the leaf surface until, finally, usually only a narrow marginal band remains green. The leaf at this stage becomes curled towards the under surface. Raspberries and strawberries develop central patches, usually yellow or red tinted, and then similar marginal bands, leaving green, horseshoe-shaped bands between the two tinted areas.

Gooseberries develop broad red marginal bands which gradually spread inwards, becoming paler as they do so.

In all cases of magnesium deficiency, defoliation is premature and follows closely on the development of the break-down symptoms. In advanced cases it may occur very early in the season, when fresh foliage is developed which also becomes affected with the symptoms at an early stage. No effects on the colour of the bark have been noted. Although the trees may blossom normally, the yield of fruit is seriously affected, since the spur leaves often become early affected and the trees carry too little foliage for the development of the fruits, which may consequently remain small and immature specimens. The root systems have generally been well developed and normal in character, but a considerable amount of killing of root fibres has frequently been observed.

No serious cases of magnesium deficiency have been proved in the field, but the leaf characters herein described are frequently observed. In such cases they are possibly due to high potassium conditions, but they also appear to be characteristic of certain varieties and can only be suppressed in these by drastic deficiencies of other elements.

Sulphur deficiency. The observations made relating to sulphur deficiency have been much less extensive than in the previous cases, and the effects of the treatment can be summarized by stating that, in general, they have resembled those resulting from a slightly restricted nitrogen supply. Thus foliage colour is slightly pale green, defoliation has been slightly hastened, and during defoliation brilliant orange tints have been developed. Root systems have appeared normal in character.

Diagnosis of nutritional problems in the field.

Following on the investigations relating to deficiencies, referred to in the previous section, an attempt has been made to apply the results obtained in those experiments to growth problems as they occur under field conditions. The general result has been that the features noted in the sand-culture experiments have been found of great assistance in determining nutritional conditions, but it has been found necessary to apply the results with caution, since experience has shown that the deficiency symptoms may result from

causes other than those which were responsible for them in the pot experiments. The most valuable application of the results to date has been in connexion with the field problem of potassium deficiency, which might have remained unsolved for a considerable period had it not been shown in sand cultures that marginal leaf scorch was a characteristic of potassium deficiency. It has been shown, however, that leaf scorch may result from various causes (6, 37, 45), and in field problems it has been necessary to determine the extent to which various possible causes of the trouble operated in numerous instances. The final conclusion is that the most important factor in the field problem is potassium deficiency.

Similarly, the pot results have been applied to problems of nitrogen supply and have proved of great value in the interpretation of nutritional conditions in relation to this element.

With regard to phosphorus, the chief point which has emerged is that the drastic effects due to phosphorus deficiency which are invariably recorded in sand cultures are not found to exist in the field, and indeed no case of phosphorus deficiency has been proved so far, nor has it been possible to record any significant effect from applications of phosphatic fertilizers in any critical manurial experiment.

Effects due to calcium deficiency would be expected to be most prevalent on strongly acid soils. Such soils are not normally selected for fruit-growing, though in many instances slightly acid soils are utilized. In such instances where unsatisfactory growth has resulted, the symptoms developed have been most frequently those of potassium deficiency and more rarely those of nitrogen starvation, and in all cases these elements when applied have produced the desired responses. Where liming has been tested the treatment has never produced significant growth responses.

The leaf symptoms of magnesium deficiency have proved to be widespread. They often occur on the foliage of strongly growing trees near defoliation time, especially on highly fed nursery stock and in rainy seasons. They also appear to be characteristic of certain varieties under good growth conditions in the different classes of fruits; thus in black currants the characteristic purpling is very marked in the variety Baldwin, and in gooseberries the broad red band is greatly in evidence in several varieties such as Whinham's Industry when growth is healthy, and these are only suppressed when some other deficiency, notably potassium, is acute. A case in which the magnesium deficiency leaf symptoms are strongly developed in association with a serious growth trouble in apples, variety Cox Orange Pippin on Malling No. IX rootstock, is at present under investigation, but it has not been proved so far that the causal factor is deficiency of the element.

Finally, it may be said that the method of using diagnostic symptoms in nutritional problems of trees is well worth developing, and may be expected to prove of value in forestry problems just as it has been found to be useful in fruit-tree investigations. The application of chemical methods to diagnostic work is referred to later in discussing the problems of leaf scorch and chlorosis.

Materials, soil conditions, and management factors in relation to nutritional problems.

Brief reference was made in the introductory section to the necessity of considering various factors relating to materials and environmental conditions in investigating nutritional problems of fruit trees, and some examples of effects due to certain of these were given. In the present section some concrete examples of such effects are recorded which illustrate the magnitude and importance of these effects.

Classes of fruits. In the course of investigations concerning the incidence of potassium deficiency (45), and in carrying out survey work (52) on fruit areas, it has been clearly established that wide differences exist among classes of fruits relative to their resistance to potassium deficiency and to unfavourable soil conditions. A differential response to potash manuring has also been demonstrated at a centre in Kent (47).

Varieties. Varieties of apples exhibit such wide differences in resistance to potassium deficiency that it has been possible to recommend that certain varieties should not be planted unless an adequate supply of soil potassium is available (45). This is also true of varieties in other classes of fruits, notably of plums (50) and gooseberries (46). An excellent example of differential varietal susceptibility to magnesium starvation is shown in Plate I, where it is seen that the apple variety Bramley's Seedling is much more resistant than Allington Pippin.

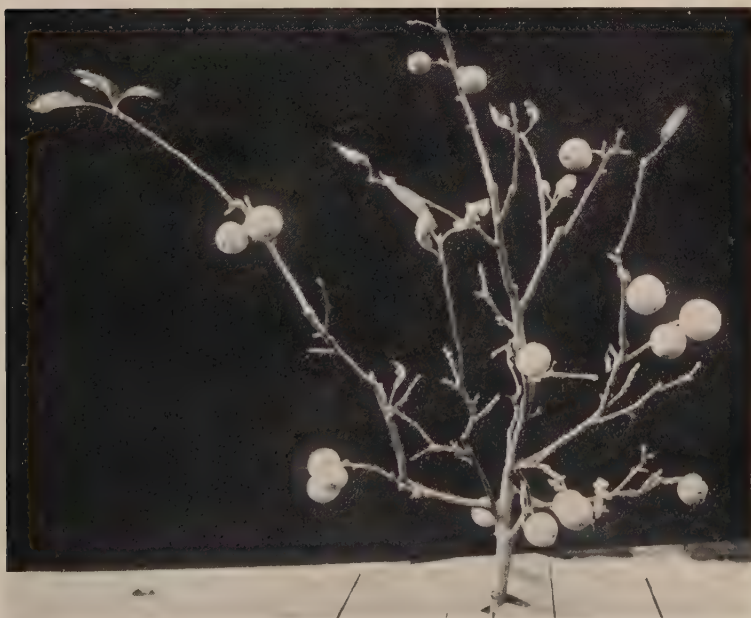
Rootstocks. Rootstocks have been shown by East Malling workers to greatly influence the nutritional conditions of fruit trees under varying conditions of soil (19), and that responses to fertilizer treatments may be greatly influenced by this factor (4, 13, 14). The writer has also shown that rootstocks are important in considering problems of potassium deficiency (40, 45, 46), and that they may exert large influences on fruit quality—storage characters and chemical composition (54). Moreover in the latter connexion it is shown that the magnitude of rootstock effect is related to manurial conditions.

Age of tree. The effect of age of tree has been studied by the writer in connexion with problems of storage qualities of fruits (54). The investigations have revealed the facts that fruits from young trees, when compared with those from older trees growing under similar conditions, are always more susceptible to storage maladies—rots and 'break-downs'—and invariably show higher contents of nitrogen and sucrose.

Soil conditions. Detailed soil and pomological surveys have been in progress in commercial fruit areas in this country since 1923 in which attempts have been made to establish correlations between various soil conditions and the growth characters of the different types of fruit trees which are grown. Surveys have already been completed of the Wisbech area (55) and in West Cambridgeshire (as yet unpublished), in East Anglia, and of the Bromyard and Ross-on-Wye areas in the West Midlands (52), while others are still in progress in Kent and in the Evesham and Cheltenham areas. Reference to the published accounts will show that it has been found possible to relate certain soil



Apple tree, variety Bramley's Seedling, growing in quartz sand without magnesium. Photograph during first season of treatment. Note only slight defoliation of terminal shoots (*c.v.* FIG. 2).



Apple tree, variety Allington Pippin, growing in quartz sand without magnesium. Photograph during first season of treatment. The variety is highly susceptible to magnesium deficiency. Note almost total defoliation. (*c.v.* Bramley, a resistant variety, FIG. 1).

conditions with particular types of tree growth and quality of fruits, with definite pathological conditions, and with various economic problems. The two major troubles due to unsuitable soil conditions have been shown to be leaf scorch, due to potassium deficiency, and lime-induced chlorosis, due to iron deficiency associated with calcareous soils. Soil acidity has not proved to be of importance, but physical texture, depth of soil, and water relationships exert profound influences.

Management factors. These factors are of great importance in fruit-growing, and the skilful grower can greatly modify 'natural' effects by various points of management. Thus the nitrogenous conditions within fruit trees can be readily regulated by a judicious combination of cultural methods and the use of nitrogenous fertilizers. Lack of cultivation, with the resultant growth of grass and weeds over the roots of the trees, cuts down the nitrogen content of the trees very drastically, and it has been frequently found in experiments that moderate cultivation is more effective in raising the nitrogen status of trees originally under grass than allowing them to remain in those conditions and relying on annual spring dressings of nitrate of soda at a rate of 5 cwt. per acre to supply the requisite nitrogen (54). Cultural practices also affect potassium requirements. Branch-pruning, bark-ringing, and fruit-thinning are practices widely used by fruit-growers to modify nutritional conditions, and must be taken into account in investigations. Some effects of these practices are recorded in the following references (53, 54).

The correlation of nutritional conditions and manurial responses to chemical composition of fruit plants.

In connexion with the various nutritional investigations carried out at Long Ashton, numerous chemical studies have been carried out with the object of ascertaining the extent to which such studies can help in elucidating nutritional problems.

The manner in which various deficiency treatments are reflected in the mineral contents of various portions of apple trees has been determined in connexion with various pot experiments (9, 41), and chemical determinations have been carried out on a very comprehensive scale in numerous investigations concerning the problems of leaf scorch and chlorosis (44, 46-50). In the deficiency experiments, it has been established that deficiencies of nitrogen, potassium, calcium, magnesium, and phosphorus are reflected in the various portions of the trees by relatively small contents of the respective elements in comparison with amounts present in adequately nourished trees, and by effects on the contents of other elements, and altered contents of total ash and dry matter. Chemical examination was found to provide a means of distinguishing between cases of chlorosis due to potassium deficiency and iron deficiency respectively; where trees representing both troubles occurred on calcareous soil areas (48-50), the leaves of potassium deficient specimens showed relatively high dry matter in fresh weight, low ash in dry matter, and low potash in ash, while those from iron deficient trees showed the reverse

condition for each feature. Chemical composition does not provide a reliable guide to storage properties of fruits (54), but nevertheless chemical features are closely correlated with the effects on fruit quality which result from factors due to materials, environment, and treatment subsequent to picking.

Pathological problems—Leaf scorch and chlorosis.

Leaf scorch and chlorosis have proved to be the two major pathological conditions of fruit trees in this country which are due to defective nutrition.

Leaf scorch. This has formed the subject of extensive investigations of the writer and other workers at Long Ashton, the major publications being the following (6, 27, 37, 43-7, 50). Papers relating to certain phases of the trouble have also been contributed by workers at East Malling Research Station (loc. cit.). The salient features of the disorder are as follows:

It has been of very frequent occurrence in practically every fruit area in the country. The typical symptoms of the trouble, the marginal browning of the leaves, can be produced experimentally in a variety of ways such as deficiency of potassium in the nutrient medium, drying out of the root system, waterlogging the root system, damaging the roots extensively, and desiccating the foliage by excessive transpiration. In the field the main cause is potassium deficiency which is often associated with relatively 'high nitrogen' conditions. Although the trouble may occur on all classes of soils, it is found most frequently associated with three conditions: open textured sandy soils with poor water supplies; shallow soils, generally eroded or poorly weathered, often fairly close textured and containing large proportions of fine sand and silt; and heavy soils in wet situations, producing seasonal waterlogging.

The most susceptible classes of fruit plants are apples, gooseberries, red currants, and raspberries, while plums, damsons, cherries, and black currants are on the whole more resistant. Varieties also show a wide range of resistance, and rootstocks exert pronounced influences. Scorching is most prevalent in dry seasons. The trouble is often very difficult to remedy when an advanced case is treated, periods of 3-5 years frequently being necessary to produce observable effects from heavy annual dressings of potash manures, say, sulphate of potash at 3-4 cwt. per acre. 'High' nitrogen conditions aggravate the trouble, and thus low cultivation and withholding of nitrogenous manures tend to mitigate scorching effects.

Chlorosis. By far the most prevalent form of chlorosis falling in the category of nutritional disorders which occurs in fruit areas in this country is that known as lime-induced chlorosis associated with deficiency of iron. A second form which is practically restricted to certain varieties of plum, especially the variety purple Pershore, results from deficiency of potassium (50). Where the latter form is present on calcareous soil areas it can be distinguished from the former type by chemical features of the leaves, as described in the previous section. In investigations at Long Ashton relating to lime-induced chlorosis, attention has been chiefly directed to ascertaining the chemical features of plants

afflicted with the trouble, to determining its incidence in relation to soil conditions, and to evolving practical methods of control. The results of these studies have been reported for the most part in a series of papers by the writer (48, 49, 51). The main points which have emerged are as follows:

The deficiency of iron from which the plants suffer is not clearly reflected by chemical analysis of the leaf and shoot portions of affected parts, but these organs invariably contain relatively low proportions of calcium associated with high proportions of potassium. The pulp of the fruits, on the other hand, shows a content of minerals similar to that in cases of potassium deficiency.

The trouble is only widespread on soils derived from calcareous rocks such as Chalk, Gault, Oolitic Formations, Carboniferous and Dolomitic rocks, and Keuper Marl where 'Skerry' deposits occur, but may be induced by excessive liming such as is frequently practised in private gardens. The incidence of the malady cannot be correlated simply with content of carbonate of lime nor with the reaction of the soil (pH); in some cases it is prevalent where the lime content is approximately 1 per cent. CaCO_3 , and in other areas the trouble is negligible where the content of this material is greater than 5 per cent.

Attempts to control the 'disease' by treatment with ferrous sulphate, whether added direct to the soil, injected into the trunk, or applied in the form of a spray, have not proved successful from an economic viewpoint. Positive reactions have been obtained by the two latter methods, but the effects have only been temporary and damage has often resulted from their use. Further work on the use of iron salts may, however, be usefully attempted with compounds such as ferric tartrate or citrate, since these appear to keep the iron in active form within the plants at higher pH values than other iron salts.

The most successful method used by us has been to grow cover-crops over the roots of affected trees, and by this means some really striking curative effects have been produced, though the method is not infallible, and may only produce slight improvement in cases where the conditions are extreme owing to soil or fruit materials. The mechanism of the action of cover-crops in ameliorating the chlorotic condition has not been ascertained, but the treatment was first attempted with the idea that local supplies of iron might be rendered available to the trees through the increased production of carbon dioxide in the soil due to the root systems of the cover-crops. Various cover-crops, such as grasses, clovers, lucerne, and weeds from cessation of cultivation, have been tested, and all have produced favourable effects.

Orchard factors determining fruit quality.

The forester is not normally interested in fruit quality problems other than the properties of seeds. For this reason no detailed account of investigations relating to the bearing of nutritional conditions of trees on fruit quality will be given, but it will suffice to mention that nutritional factors greatly affect the qualities of fruits, especially the pulp portions, and that the study of fruit properties affords a further means of assessing the effects of nutritional conditions on tree performance. A summary of the effects on fruit quality of the

more important factors affecting nutritional processes in trees has been published (54).

CONCLUSION

In the foregoing account an attempt has been made to summarize the salient points which have emerged from investigations at Long Ashton relating to the nutritional problems of fruit plants, and brief reference has been made to the main investigations which have been carried out in the past both in this country and abroad and to the trend of recent work at various centres. The account is of necessity of rather a sketchy character, and it is not put forward as an exhaustive digest of the modern position of horticultural research concerning the nutrition of fruit trees. It is hoped, however, that it will serve to introduce workers on forestry problems to the literature relating to the nutrition of fruit plants, and that the results which have been summarized may serve a useful purpose in considering the development of possible lines of work relating to problems which arise in connexion with the nutrition of forest trees.

SUMMARY

1. The objects of investigations relating to the nutrition of fruit trees are briefly stated, and reference is made to the similarities and differences in the problems of the fruit specialist and the forestry expert.

2. The factors which require consideration in nutritional investigations concerning fruit trees are given, and examples are quoted of some general effects due to these.

3. A brief outline of investigations carried out in the past and of more recent studies in this country and abroad is given.

4. The main subjects of investigation relating to problems of fruit-tree nutrition which have been studied at Long Ashton are outlined, and the chief results which have been obtained are summarized, and reference made to the more important publications describing the various investigations.

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A STUDY OF SOME YORKSHIRE MOORLAND SOILS

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INTRODUCTION

THE investigation described in the following pages was undertaken at the request of the Forestry Commission on an area acquired for afforestation in the North Riding of Yorkshire. The investigation was limited to parts of Wykeham Low Moor and Allerston Low Moor, respectively five and fifteen miles west of Scarborough. These areas comprise tracts of moorland which in all probability have never carried a natural forest vegetation, and their soils are entirely different from the soils that have developed in the once heavily wooded dales of the region.

The soil type of the dales is the 'brown earth', characterized in the vertical section (profile) by the dark brown to black colour of the top layers of the mineral soil, merging without any sudden change into the colour of the sub-soil. The soil type of the heather moors is the 'podsol'. Podsoles are characterized by the strong leaching from their surface layers of the weathered material, which accumulates at a lower depth in the soil. The zone of leaching is seen in the profile by the grey colour of the soil, which changes sharply to a red-brown at the point where the zone of accumulation begins.

The brown earth is the general soil type of regions where the climatic climax is deciduous forest: the podsol of regions where the climax is coniferous forest or heath. The development of a brown earth or a podsol is largely dependent on the development of the corresponding vegetation, and a brown earth may degenerate into a podsol as the soil becomes exhausted and the deciduous forest is supplanted by coniferous forest or heath. Podsolization often indicates that a stage in soil development has been reached at which the soil is no longer suited for deciduous forest, although it may still carry excellent coniferous forest. In the further development of a podsol, soil exhaustion becomes intensified, until the soil can no longer support a crop of trees, and it degenerates to a moor.

Since the Yorkshire Moors have probably never carried forest, it is unlikely that the present podsoles are degenerated brown earths, and it may be assumed that the soils have been podsolized ever since the moors were first dominated by heather. There is, therefore, no *a priori* reason for assuming that the soils have already degenerated beyond the stage at which they can carry forest. This is obviously a question that depends on all the factors of the locality, and can only be settled by actual afforestation. The soil, however, is one of the most important factors, and is to some extent under the control of man. The possible extent and the most profitable direction of its control can best be ascertained from

a study of the soil-forming agencies, and the manner in which they have affected the nature and productivity of the locality.

The present work has been based on a study of the soil profile. Every feature in the profile is a result of definite soil processes, and the whole presents a complete, though never fully understood, picture of the soil's history. Since approximately the same external agencies which have produced the present profile will continue to act on the soil, it should be possible to predict their effects under conditions modified by soil treatment, or conversely, to form an idea of the treatment most likely to lead to any desired result.

OUTLINE OF THE WORK

A large number of profiles displayed in pits and along the sides of plough furrows were examined and described in the field. It soon became evident that in its main features the soil type was constant over the whole area, and that it would be possible to generalize about the development of the soil from a detailed examination of a few profiles, utilizing the variations observed in the field to explain the different stages that lead up to the development of the mature soil. In this article a brief description of a typical profile is given, and a generalized description of the different horizons, and of the variations observed in each. It is then shown how the drainage and water relationships of the moors are affected by the structure of the soil profile. The results of laboratory analyses follow, and their bearing on the field observations is discussed. In conclusion, the main features of the soils, with special reference to their development, are summarized, and suggestions are made, in the light of the information obtained, with regard to the possibilities of soil amelioration from the forester's point of view.

NOMENCLATURE USED IN PROFILE DESCRIPTIONS

The profile is divided into 'horizons', a horizon being a layer of soil distinguished from the soil above and below it by some special characteristic such as colour, texture, chemical composition, &c. In the present work, colour has been taken as the basis of horizon differentiation. The boundary between two horizons may be well defined (e.g. between A and B, below), or else two horizons may merge into one another without any abrupt change (e.g. B and C).

The different horizons are designated by capital letters. 'A' represents the horizon of eluviation or leaching; 'B' the horizon of illuviation or deposition; 'C' the horizon of parent rock, unchanged by soil processes. The A, B, and C horizons can each be further differentiated, if any marked change in appearance occurs within the main horizons themselves. Numerals are affixed to the capital letters to define these subordinate horizons.

In the descriptions horizon differentiation has been kept as simple as possible, and in order to avoid confusion it has been necessary to use a nomenclature slightly different from that usually adopted in soil studies.

DESCRIPTION OF THE LOCALITY

Topography. The topography of both areas is flat, with a slight but appreciable inclination to the south. The highest point on Allerston Moor was 800 feet, on Wykeham Moor 700 feet. On both moors the heath-land extended southwards approximately to the 550-foot contour.

Climate. The uplands are exposed to a great force of wind from all directions. The rainfall is 32–36 inches per annum and is fairly evenly distributed throughout the year.

Geology. The surface stratum of Allerston Moor is the Middle Calcareous Grit, and of Wykeham Moor the Lower Calcareous Grit, of the Middle Oolite. The strata are described as siliceous sandstones. Any calcareous matter originally present has long since been washed away, and the rocks now have a strong acid reaction. Both strata below the actual soil have the same orange-yellow colour. In several places, especially on the Lower Calcareous Grit, strongly weathered stones crop out at the surface, but their presence has no apparent effect either on the vegetation or on the general features of the soil profile.

No other geological formations were encountered on the areas investigated, although a few observations for comparative purposes were made on the neighbouring Brompton Moor, where the formation is a coarse yellow sand—the passage beds, deposited between the Middle and Lower Calcareous Grits.

Vegetation. The moors are mainly dominated by *Calluna vulgaris*, which often grows to the exclusion of everything else. Most of the area has been burnt over at one time or another, and after burning temporary associations with species of *Erica*, *Scirpus*, *Juncus*, *Nardus*, &c., invade the ground, giving place to *Calluna* as the effects of burning disappear. Under the few scattered trees that occur, the ground flora may contain grasses, especially *Aira flexuosa*.

THE SOIL PROFILE

The following description of a soil profile on Allerston Moor is representative of the normal type that was encountered.

Horizon.	Depth.	Description.
	cm.	
A ₀	0 – 8	Black decomposed peat, matted with heather roots.
A ₁	8 – 19	Light grey, sandy, with occasional grey pebbles. Roots frequent, especially in the lower part.
A ₂	19 – 19 $\frac{3}{4}$	Moist black peat, from decomposing roots.
B ₁	19 $\frac{3}{4}$ – 20	Brown hard-pan, black on upper surface.
B ₂	20 – 30	Red-brown, compact, with a laminar structure and dark horizontal streaks.
C	30 – 50	Yellow, changing to orange; hard and compact.

General descriptions of each horizon. A₀. The peat is usually well decomposed, showing little sign of plant structure. It varied in thickness from

a shallow surface covering to 17 cm. The variations in the thickness of the peat are mainly due to the occurrence of frequent fires, which not only destroy the peat, but reduce the water absorbing capacity of what remains, and allow a vegetation with greater water requirements to flourish. The peat appears to be the main source of the heather's mineral nutriments, as shown by the far greater number of roots found in the peat than elsewhere in the soil profile.

A₁. This horizon has been leached by humic acid solutions percolating through from A₀. It is stained dark grey by the presence of finely dispersed humic matter, but when this is removed by ignition an almost pure white residue is obtained. The horizon attains a maximum thickness of 12 cm. on both moors wherever the profile is fully developed. Shallower A₁ horizons, 5–10 cm. thick, indicate that the profiles are incompletely developed (p. 31). The soil feels loose to the touch, is freely permeable to water, and is easily penetrated by heather roots, which are unable to penetrate below the A horizon, and accumulate at its base, where they decompose and form

A₂. A thin peaty horizon, very characteristic of these soils.

B₁ and B₂. Below A₂ an abrupt change in the soil profile occurs. The loose dark-grey soil of the A₁ horizon is replaced by a dark-brown hard-pan, B₁, never more and often less than $\frac{1}{2}$ cm. thick. Below the pan comes a compact red-brown horizon, B₂, which a few centimetres deeper gradually changes into the yellow C horizon.

The B horizon is the 'illuvial' horizon, in which the material leached from A has been redeposited. It is consequently rich in those substances of which A has been deprived, the accumulation of iron being obvious by the red-brown colour of the whole B horizon.

The pan, B₁, may be deposited over considerable areas as an unbroken and almost level band. The level pan occurs with great regularity at a depth of 10–12 cm. below the surface of the mineral soil. Many places, however, were found where the pan had a more irregular, wavy form, and exhibited frequent discontinuity, although a casual inspection of the profile gave the impression of a continuous pan, owing to the dark colour of the thin and unbroken A₂ horizon, which was always present.

Wavy pan is nearly always deposited nearer to the surface than the level pan. The deposition of the level pan, at a regular maximum depth of 12 cm., seems to mark the end of the development of the podsol profile; wavy pan indicates that the final stage of profile development has not yet been reached. There was evidence that the wavy pan is an unstable and temporary deposit, which tends to flatten out to a level pan at the normal depth of 12 cm.

An example of the flattening out of a large pan wave is illustrated in Plate II, Fig. 1, the photograph being taken along the side of a plough furrow on Wykeham Moor. The surface horizon consists of 2–3 cm. of peat, followed by the leached A₁ horizon (3–7 cm.). At 7 cm. on the rule, a narrow dark band occurs, composed of the peaty material of A₂. There is no trace of hard-pan below it, but instead a very light-grey horizon (A₃), which extends to 12–13 cm.



FIG. 1. Podsol profile on Wykeham Moor, showing well-developed A_3 horizon.

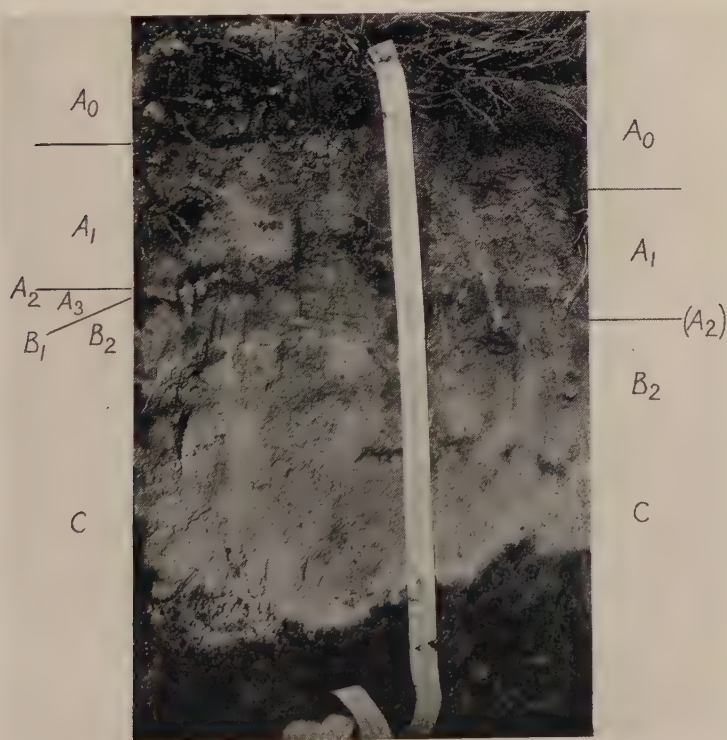


FIG. 2. Podsol profile on Wykeham Moor, showing broken wavy pan (absent on the right of the photograph), laminar B_2 horizon, and a thin A_3 horizon on the left.

At 12–13 cm. there is a very thin hard-pan, and then the red-brown B_2 horizon, merging at about 20 cm. into the lighter coloured C horizon at the bottom of the furrow.

An exceptional feature of this profile is the extra horizon, A_3 . Analysis of this horizon (p. 36) shows that it contains considerable quantities of deposited material, though not so much as a normal B horizon. There can be little doubt that it represents an old B_2 horizon now undergoing leaching, and that a pan was previously deposited immediately below A_2 . To the left of the rule a point can be seen where the pan lies almost immediately below the A_2 horizon. Here the A_1 horizon has nearly attained its maximum thickness.

A possible explanation of this phenomenon is as follows. The pan is normally deposited when the concentration of material taken up by percolating humic acid reaches a certain critical amount at which the humic acid becomes insoluble. This critical concentration is usually reached when the humic acid has percolated through 12 cm. of mineral soil. But some local difference in the soil properties may cause the pan to be deposited at a higher level before the critical concentration is reached. This pan contains less material than pan deposited at lower levels, and it can therefore be redissolved by percolating humic acid without the latter becoming saturated and insoluble. The humic acid will then leach the B_2 horizon (now A_3), and finally be deposited as pan at the normal depth. The pan now contains so much material leached from the surface horizon that it cannot be dissolved by humic acid solutions without being immediately reprecipitated *in situ*. This phenomenon was frequently observed, especially on Wykeham Moor. It seems to indicate a tendency towards the ultimate development of a stable and uniform profile over large parts of both areas.

The B_2 horizon is lighter in colour than the pan, and represents a less concentrated zone of deposition. It usually has a horizontally laminated structure, and the few roots that penetrate through the pan tend to spread themselves laterally between the laminae, and leave dark-coloured streaks in the soil when they decompose. In consequence also of its laminar structure, the horizon is slightly permeable, and water can flow laterally between the laminae. The vertical drainage of water, however, is very much impeded.

On the top of Allerston Moor it was observed that pine seedlings which had been sown on overturned plough furrows, had failed wherever the red B horizon had been brought to the surface, though they were doing quite well where they had been sown in the grey soil of the overturned A horizon. It is possible that the large amounts of iron and aluminium in B have had a poisonous action on the seedlings.

C. The intensity of colour of the B horizon diminishes gradually with the depth, and at about 25–30 cm. below the surface the soil assumes a yellow colour, which sometimes darkens to orange at a depth of about 50 cm. The yellow and orange C horizon is that part of the profile which has not been altered by the present soil-forming processes. It is made up of a compact sand, less hard to the touch than the B horizon, but unlike the latter it

shows no signs of a laminar structure, and appears quite impermeable. Only occasionally have a few very fine rootlets been able to penetrate it.

Summary. The main properties of each horizon may be summarized as follows.

A₀. An acid heather peat, decomposing very slowly, and capable of absorbing large quantities of water.

A₁. The surface horizon of the mineral soil. It has a grey colour, in consequence of having been leached of iron by humic acid from the peat. It is quite permeable and easily penetrated by roots.

A₂. A thin horizon, composed of peaty material from rotting roots that have accumulated at the bottom of A₁.

A₃. A light grey horizon, only found where the pan was formerly deposited abnormally near the surface. It represents an old horizon of deposition now being leached.

B₁. A thin hard-pan, formed by the deposition of material removed from A₁. Roots only penetrate it occasionally. Although pan is found almost everywhere, it is not continuous over large areas, frequent fissures being encountered. The pan tends to form at a fairly constant depth of 12 cm. below the surface of the mineral soil.

B₂. A compact horizon, containing material leached from A₁, but less concentrated than in the pan. It usually has a laminar structure, enabling roots to penetrate into it, and water to percolate through it, laterally. B₂ merges, without any sharp change, into C, an impermeable, yellow-orange subsoil that has not been altered during the development of the present profile and takes no direct part in the nutrition of the vegetation.

THE DRAINAGE AND WATER RÉGIME OF THE SOILS

It has already been noted that the A horizon is quite permeable to water, that B is much less so, while C is practically impermeable. This was evident from field observations during the winter. Although the permanent water-level was never reached, almost all the pits examined (which had been dug some months previously) contained a considerable depth of water, which in a few instances reached up to the level of the pan, a depth of 2 feet or more in the pit. Usually, however, the water-level did not reach above the top of the C horizon. Sometimes water could be seen draining into the pits from the top of the pan. There seemed to be little or no leakage away of water through the walls and bottom of the pit in the C horizon.

These facts demonstrated the relative permeabilities of the different horizons. A quantitative expression for them was obtained in the laboratory in the following way. In order experimentally to determine a soil's permeability, it is essential to retain the natural structure of the tested sample. This was done by collecting the samples by pressing cylindrical tobacco tins vertically into the soil at the required depth. A hole was punched in the bottom before taking the sample and the lids were put on afterwards to retain the moisture. In the laboratory, the soil was removed from the top of the tins to

a depth of 4 cm., leaving 8 cm. of soil. The bottom of each tin was pierced with 12 holes, and 100 c.c. of water were run through the tins, which were then left overnight with the lids on. 100 c.c. of water were then introduced into the tins on top of the soil, and the time noted in each case at which the first drop drained. The water draining through was collected in graduated cylinders, and the amount that drained was measured at intervals.

Percolation Experiments

(1) Allerston Moor: Middle Calcareous Grit.

<i>Horizon</i>	<i>Depth (cm.)</i>	<i>Time (minutes)</i>	<i>c.c. water drained</i>
A	6-14	5	95
B	18-26	34	35
		60	55
		120	96
C	30-38	34	4
		60	8
		120	15
		240	36
		300	40
		660	95

(2) Wykeham Moor: Lower Calcareous Grit.

A	5-13	5	90
B	18-26	36	32
		62	50
		120	87
		150	94
C	30-38	30	4
		60	9
		120	19
		240	40
		350	52
		550	95

(3) Brompton Moor: Passage Beds.

A	10-18	5	90
B	22-30	13	90
C	40-48	24	90

The Brompton Moor profile has been added for comparison, to show the far greater permeability of the Passage Beds compared with the Calcareous Grits. The results, of course, are only approximately accurate. Nevertheless, they show that if the permeability of the A horizon is taken as 100, that of B is approximately 4, and of C 0.75.

If the results of these experiments are taken in conjunction with the field observations, the conclusion is reached that the A horizon is freely permeable, the B horizon is slightly permeable, especially in a lateral direction, and the

C horizon is very impermeable. The thinness of the pan, and its frequent discontinuity, make it improbable that it has any great influence on the soil water régime.

The extent of root penetration in the different horizons is in the same order as their relative permeabilities. The impermeability of the parent rock alone is sufficient to explain the absence of roots below the pan. The actual deposition of pan seems to make little difference. Thus, on the permeable soil of Brompton Moor (cf. percolation experiment (3)) a profile was seen with a well-developed hard-pan at 20 cm., through which roots of heather and grass had penetrated freely. The soil here is quite permeable in all horizons, and notwithstanding the presence of hard-pan, root penetration was unhindered to a depth of at least 70 cm. Furthermore, places were found on the impermeable soils of the Calcareous Grits, where pan was absent, yet root penetration ceased completely at the bottom of the A horizon.

The drainage of the moors is regulated by the different permeabilities of the soil horizons. Part of the rainfall is held up by the peat and vegetation, and never reaches the mineral soil. The rest drains freely through the A horizon, and then laterally along the surface of the pan and through the laminae of B. The main drainage system is therefore in a lateral direction, over and through the B horizon. Since the B horizon begins at an approximately constant depth, the drainage follows the contour of the moors, and is unimpeded in places with a sloping topography. On level ground, and still more in hollows, the run-off is not so satisfactory, and a tendency to high moor formation is manifested. A good example of this may be seen above Dalby Warren, on Allerston Low Moor, where there is a large level plateau, the contour remaining practically unchanged over an area of a square mile or more. The vegetation is that of a rather moister moor. *Calluna vulgaris* is generally dominant, mixed with *Molinia coerulea* (which may become dominant), *Nardus stricta*, *Scirpus caespitosus*, *Erica tetralix*, *Eriophorum vaginatum*, and occasionally *Sphagnum*. There are several wide shallow hollows, in the centre of which small ponds are sometimes found, the level of the standing water coinciding with the top of the C horizon of the soil at the margin. In some places the beginnings of high moor can be seen by the slightly convex form of the surface, raised above the general contour level, with *Eriophorum* dominant, and *Sphagnum* frequent.

CHEMICAL AND PHYSICAL PROPERTIES OF THE SOILS

Two profiles were selected for laboratory examination, one from Allerston and one from Wykeham Moor. The following determinations were made:

- (1) Mechanical analyses.
- (2) Complete chemical analyses of the A and C horizons.
- (3) Determination of material soluble in acid ammonium oxalate.

Acid ammonium oxalate has a powerful solvent effect on the soil colloids, but it does not attack the unweathered skeletal material, which has not been changed during soil development. The results of these

analyses are therefore a quantitative measure of the movement of the different weathered constituents through the soil profile (1).

(4) Acidity (pH value).

(1) *Mechanical Analyses.*

Profile I. Allerston Low Moor: Middle Calcareous Grit

<i>Horizon.</i>	<i>Depth.</i>	<i>Coarse Sand.</i>	<i>Fine Sand.</i>	<i>Silt.</i>	<i>Clay.</i>
	cm.	%	%	%	%
A	10-13	9.5	45.1	30.0	10.0
A	16-19	11.0	41.9	26.5	15.0
B	21-24	9.8	46.8	23.8	15.0
B	26-30	8.7	47.4	26.5	15.0
C	45-50	6.3	42.3	24.5	25.5

Profile II. Wykeham Low Moor: Low Calcareous Grit

A	3-5	30.6	33.7	19.0	5.0
A	5-7	25.0	37.8	19.0	7.5
A	8-11	26.8	33.6	19.5	10.0
C	23-30	34.7	30.1	19.0	15.0

There has been some washing down of the clay fractions, but the differences in the mechanical compositions of the A and C horizons cannot wholly account for the very great differences in their relative permeabilities. In the parent rock the particles are probably cemented together by a yellow ferruginous material which is removed in the leaching process, leaving a loose and permeable A horizon. The infiltration of the leached material into the B horizon may account for the latter's laminar structure.

Complete Chemical Analyses.

Profile I. Allerston Low Moor

<i>Horizon.</i>	<i>Depth.</i>	<i>Loss on ignition.</i>	<i>SiO₂.</i>	<i>Al₂O₃.</i>	<i>Fe₂O₃.</i>	<i>CaO.</i>	<i>Na₂O+K₂O.</i>	<i>PO₄.</i>	<i>N.</i>
	cm.	%	%	%	%	%	%	%	%
A	10-13	10.03	79.5	6.32	0.28	0.47	1.5	0.032	0.19
C	45-50	6.85	69.6	9.00	9.72	0.49	1.5	0.057	0.05

Profile II. Wykeham Low Moor

A	5-7	7.75	79.8	4.97	0.31	0.58	1.7	0.030	0.15
C	23-30	5.43	74.5	5.08	5.38	0.55	1.8	0.036	0.05

Note: The amounts of magnesia (MgO) were too small to be determined.

It will be noticed that while the main difference between the two C horizons is in the amounts of sesquioxides (Al₂O₃ and Fe₂O₃) the leaching process has largely removed this difference in the A horizons, the compositions of which are almost identical.

Total bases are very low, and there is no appreciable difference in the

amounts in the A and C horizons. A considerable leaching of phosphate from the A horizon has, however, taken place.

The high nitrogen content of the A horizons is due to the presence of much organic matter. These figures are in no way an index to soil fertility. The humus nitrogen is unavailable to plants, and its rate of mobilization in these soils is undoubtedly very slow.

DETERMINATION OF MATERIAL SOLUBLE IN ACID AMMONIUM OXALATE

Only iron, aluminium, silica and phosphate were estimated. These are the chief substances involved in podsolization, and the appended tables are thus a summary of the chemical results of that process. The pH values are added in the last column of the tables.

Profile I

<i>Horizon.</i>	<i>Depth.</i>	<i>Loss on ignition.</i>	<i>SiO₂.</i>	<i>Al₂O₃.</i>	<i>Fe₂O₃.</i>	<i>PO₄.</i>	<i>pH.</i>
	cm.	%	%	%	%	%	%
A ₀	0-5	—	—	—	—	—	3·24
A ₁	10-13	10·03	0·03	0·10	0·10	0·024	3·27
A ₁	15-19	10·73	0·06	0·10	0·14	0·038	3·50
B ₁ (pan)	19-19½	28·45	0·31	2·06	6·75	0·085	3·71
B ₂	21-24	7·63	0·04	2·50	3·14	0·080	3·56
B ₂	26-30	6·11	0·01	0·55	0·80	0·034	3·86
C	45-50	6·85	nil	0·30	0·31	0·032	3·88

Profile II

A ₀	0-3	—	—	—	—	—	3·20
A ₁	3-5	6·93	0·11	0·16	0·10	0·024	3·20
A ₁	5-7	7·75	0·06	0·20	0·09	0·018	3·20
A ₃	8-11	8·53	0·11	0·65	0·41	0·035	3·56
B ₁ (pan)	11-11½	16·96	0·09	2·44	5·76	0·039	3·65
B ₂	12-14	9·69	0·08	2·37	2·76	0·041	3·91
C	23-30	5·43	0·08	0·48	0·37	0·024	3·93

The most obvious feature of the tables is the accumulation of iron and organic matter (included in the loss on ignition) in the pan, and to a lesser extent in the B₂ horizon. There has also been an appreciable accumulation of phosphate in the B horizon, although the figures for the A and C horizons are approximately the same. The figures for the A₃ horizon of Profile II support the view that it is an old horizon of deposition, now being leached. The pH values indicate a very high degree of acidity in the peat and surface horizons. In both profiles the acidity decreases steadily with the depth, except for a slight discrepancy at the pan in Profile I. This very high acidity in the surface horizons would probably be a limiting factor to the growth of any but the least exacting type of vegetation.

SUMMARY

The most obvious feature of the soils is their strong podsolization—a consequence of the accumulation of acid heather peat on the already very acid

parent rock. One result of podsolization has been the deposition of a thin hard-pan, below which root penetration and plant nutrition virtually cease. Hence, the deeper the pan, i.e. the thicker the leached A horizon, the greater is the amount of soil from which the vegetation can draw its nutrients. On Allerston and Wykeham Moors there appears to be a maximum thickness (12 cm.) of the leached horizon, at which further development of the podsol profile ceases. Over much of the area this stage has already been reached. In certain places the leached horizon is less than 12 cm. thick, but there are indications that it is in the course of deepening to the usual maximum of 12 cm.

The pan protects the underlying impermeable rock from weathering, with the result that most of the water drains off laterally along the top of the pan. But where the moor surface is quite flat, or concave, this lateral drainage is incomplete, and the surface soil resting upon an impermeable stratum tends to become waterlogged, and high moor formation sets in.

The yellow parent rock (C horizon) is quite impermeable. On account of its much greater thickness, it offers far more resistance to the passage of roots and water than the thin hard-pan; the importance of the pan lies in the fact that it has prevented the deepening of the biologically active soil horizon by cutting off the subsoil from the processes that have made the surface horizon permeable.

The soils are very strongly acid, and correspondingly poor in basic plant nutrients. The leaching of the surface horizon has, however, mainly affected compounds of iron and aluminium, and there is very little difference between the horizons in regard to their supplies of basic nutrients, although the B horizon is richer in phosphates than either A or C. The exceptionally high acidity of the surface soil is probably the most serious feature of these soils, and the most difficult to combat, from the point of view of their productivity.

POSSIBILITIES OF SOIL AMELIORATION

A. *Factors limiting soil productivity.*

(1) *The surface peat.* This contains a considerable proportion of the total soil nutrients, and as it is very slowly decomposed the nutrients remain for the most part unavailable for the vegetation. The peat is very acid, holds back much water from the vegetation, and greatly impedes the free aeration of the soil.

(2) *The hard-pan.* Its chief disadvantage is not so much that it offers an impenetrable obstacle to roots and water (this being more a property of the parent material) as that it prevents the deepening of the podsol profile, and thus limits the depth of the biologically active soil. Under the prevailing conditions, biological activity, including plant nutrition, is confined to the leached horizon, and hence the deeper the horizon the more productive the soil. In the presence of pan, therefore, a more or less definite limit is placed on soil productivity.

(3) The nature of the parent material, its impermeability, lack of nutrients and acidity.

B. *The Treatment of the Limiting Factors.*

The most effective way of improving the soil would be to increase its active depth, at present limited by the pan to the 12 cm. of the A horizon. No appreciable increase in the actual nutrient value of the soil will be gained by any treatment except in so far as it increases the depth from which nutrients can be drawn. The first aim in any scheme of permanent soil amelioration must therefore be the destruction of the pan, and the prevention of its recurrence. Immediate destruction of the pan can be achieved by ploughing, but in practice the pan will only be reached where the peat is relatively thin. The chief effect of ploughing will be to destroy the structure of the soil profile, but since the external factors remain the same, the ground will soon be recolonized by heather (as observation shows), and podsolization and pan formation will begin again. The benefits the soil derives from ploughing—accelerated decomposition of the peat, and improved aeration and moisture conditions—are therefore likely to be transitory unless further measures are taken to prevent the recurrence of the pan. This demands a change in one or more of the soil-forming factors, and of these the peat, whose properties are a product of the combined effects of climate, geology and vegetation, is most amenable to treatment, although it is doubtful whether, under the best conditions obtainable on the moors, a sufficiently favourable humus layer can be produced to ensure the non-recurrence of pan. The most that can be done is to aim at improving the condition of the peat through the vegetation, and in such a way that the most readily decomposed, i.e. the least acid, humus possible under the existing circumstances is produced. To do this a vegetation should be established which utilizes to the full the basic nutrients of the soil, so that the humus formed shall also contain a high proportion of bases.

If soil improvement were the sole aim of the forester, the choice of species would fall on one with high mineral requirements, capable of producing a basic, or only weakly acid humus. For this purpose, of the species possible on the moors, birch would probably be the most satisfactory. Like other deciduous trees, birch tends to produce a less acid humus than conifers, and its humus is exceptionally strongly 'buffered', i.e. its reaction varies less than that of most other species with the reaction of the soil in which the tree grows. Moreover, the form and physical condition of birch leaves produce a loose and well-aerated humus layer, well adapted for the growth of micro-organisms. There would probably be a smaller and less acid accumulation of raw humus under birch than under any other species, and podsolization would progress more slowly.

Larch stands midway between most deciduous and coniferous species with regard to the reaction of its humus, but on an acid soil it is more likely to produce an acid humus than birch, and the physical nature of the litter is also less favourable for decomposition.

Scots pine, by reason of its deep rooting system and the relatively loose nature of its litter, would probably be more suited to the soil than Norway

spruce, which is shallow rooting and produces a very compact litter. Both species yield an acid raw humus. Under conditions similar to those prevailing on the Yorkshire Moors, spruce, especially in the second generation, tends to root entirely in the humus layer, and becomes very liable to storm damage.

The addition of large quantities of lime would have an immediate and probably lasting effect in reducing soil acidity and increasing the whole biological activity of the soil. With sufficient lime podsolization could be prevented.

In conclusion, it may be emphasized that the most urgent need is to deepen the soil horizon into which the tree roots can penetrate and from which they can draw their nutrients and their water-supply. Deep ploughing is perhaps the best way of achieving this object, but the increase in depth obtained by ploughing is small, and likely to be transitory unless further measures are taken to prevent the redeposition of the pan. In the absence of pan, the depth of soil available to the vegetation may increase by the natural weathering of the B and C horizons. The prevention of pan deposition requires an alteration in the course of soil development, and this can only be done by changing the condition of the humus. This is essentially a question of controlling the vegetation. The type of vegetation most likely to produce a good humus condition is that which utilizes to the utmost the mineral resources of the soil.

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THE INFLUENCE OF NUTRITION ON THE RELATIVE ROOT AND SHOOT DEVELOPMENT OF FOREST-TREE SEEDLINGS

BY R. N. ALDRICH-BLAKE

INTRODUCTION

IN a previous communication the writer (1) showed that Corsican pine seedlings, grown in sand with an adequate supply of potassium, magnesium, calcium, iron, phosphorus, and sulphur, responded to progressive increase in the supply of nitrogen as ammonium nitrate by a significant decrease in relative root weight. He quoted several authors who found that such a reaction held for other plants; drew attention to the important work of Reid (9, 10, 11) and Shirley (13), which indicates that plants with a high carbohydrate/nitrogen ratio have relatively heavy roots, and vice versa; and brought together the results of experiments which show that increase of other essential mineral nutrients may also lead to a reduction of relative root weight. Finally he pointed out the probable importance of these facts in nursery practice. In well-manured beds large plants can be grown in a shorter time than in unmanured beds. But such large plants may be top heavy, owing to their relatively light roots, and in consequence they may be intolerant of moving.

Additional literature on the influence of environment on relative root and shoot development has since been consulted. This has strengthened the impression that the majority of plants react to increase of nitrogen supply by a decrease in relative root weight. In sand-culture experiments Rippel and Ludwig (12) showed that the relative root weight of sunflowers decreased throughout the growing season, and was at all periods higher in plants receiving little ammonium nitrate than in those receiving much. Loomis (6) recorded a similar response for tomato plants. And, in a study shortly to be published, the present writer showed that *Casuarina equisetifolia* plants, fertilized with ammonium nitrate or provided with a symbiotic nitrogen fixing bacterium, had a lower relative root weight than plants from which nitrogenous fertilizers and the bacterium were withheld.

Further evidence that plants react to an increase of other mineral nutrients by a decrease in relative root weight has been obtained. Thus Parker (8) found that soy-beans and maize in water culture produced a relatively lighter root the greater the supply of phosphate. Kissler (5) records that the relative root weight of wheat decreased as the quantity of available potassium was increased, though the reverse behaviour resulted from increase in the supply of calcium. Loomis (6) watered one series of his tomato plants heavily, another lightly; and the former had a lower relative root weight. Engler and Glutz (3) found that plants used for green manuring in Swiss forest nurseries had a lower relative root weight the richer the soil, and Burger (2) has recently shown that the same rule holds for 4-year old plants of beech, oak, sweet chestnut, spruce,

silver fir, larch, and Scots pine. Wahlenburg (14) treated nursery plots of western yellow pine with a variety of mixtures of sodium nitrate, superphosphate and potassium chloride, and found that plants receiving any or all of these manures had a lower relative root weight than unmanured controls. He concludes: 'It may be seen from the table that without exception the fertilizer treatments, as in the earlier experiments, were detrimental to good balance, top heaviness having been invariably increased by fertilization.'

Thus the majority of plants appear to devote more of their substance to root formation if there is a deficiency of any of the materials normally obtained by the roots than if these nutrients are present in abundance, while plants restricted in their photosynthetic production by low light intensity or subnormal CO_2 supply attempt to overcome this handicap by devoting more materials to photosynthetic organs. No appreciable advance has been made towards a closer understanding of the causal mechanism whereby plants respond to their environment in a manner apparently so useful. But the writer's work on *Casuarina equisetifolia*, combined with Reid's (10) discovery that strains of wheat with much nitrogen in the grain have relatively light roots and vice versa, shows that nitrogen depresses relative root weight by an internal effect on the metabolism of the plant, and that nitrogenous salts exercise their influence by virtue of the contained nitrogen, rather than by their physical qualities. It was thought that the reaction might be explained simply if more mineral nutrients were required for shoot than for root formation. Accordingly analyses of the nitrogen, phosphate, and potassium content of shoots and roots of a variety of plants were consulted, but no general rule could be deduced from this study.

It was evident that the work on Corsican pine should be followed by a study of the reaction of other forest-tree seedlings to increase of nitrogen supply; for, although we have data from nursery experiments, more accurate results can be obtained in sand culture. Accordingly seedlings of five more species were tested in this respect. The work at the Boyce Thompson Institute (9, 10, 11, 13) indicated that large plants with relatively heavy roots might be obtained by growing them in a rich mineral solution with a supernormal supply of carbohydrates. In one experiment, therefore, the influence of adding sucrose to the nutrient solution was investigated, and in another was studied the effect of enriching the atmosphere with CO_2 .

THE EFFECT OF NITROGEN ON THE DEVELOPMENT OF SEEDLINGS OF SEVERAL TREE SPECIES

The reaction of seedlings of five tree species to a progressive increase in the supply of ammonium nitrate was studied at Kennington nursery in 1931. Norway spruce, *Picea excelsa* Link, and Japanese larch, *Larix leptolepis* Endl., were selected as further representatives of the Abietineae, and on account of their importance in British forestry. *Cupressus macrocarpa* Hartw., and *Cryptomeria japonica* Don, were chosen as representatives of the Cupressineae and Taxodineae respectively, and because of their introduction in several parts

of the Empire. The common ash, *Fraxinus excelsior* L., was the sole representative of broad-leaved trees.

Method of growing the plants.

The seedlings were grown in boxes of internal dimensions $18'' \times 18'' \times 16\frac{1}{2}''$ deep, constructed of stout tongued and grooved deal. Four drainage holes, 1 inch in diameter, covered with fine mesh metal gauze, were evenly spaced in the base of each box, one side of which was affixed by screws, and could thus be readily detached to facilitate washing out of the roots at the end of the experiment. Sixty-three such boxes were set up on $3'' \times 2''$ creosoted scantlings, in order to hold them off the ground, and thus prevent rotting and promote free drainage. In February each box was filled with about 2 cwt. of quartz sand, which had adequate time to settle before the seed was sown. Fortunately this sand, obtained from Bedfordshire, was very clean, and in consequence it did not need to be sieved.

In each box sixty-four seedlings were grown, spaced 2 inches apart in eight rows of eight. The ash was grown alone, sixty-four seedlings per box. But a smaller number of coniferous seedlings appeared sufficient; and larch and spruce were therefore grown together, thirty-two seedlings of each species per box, four rows of eight larch on one side and four rows of eight spruce on the other; and *Cupressus* and *Cryptomeria* were similarly mixed in the boxes. Such an arrangement was admittedly not ideal, in that one species might make greater demands on the nutrient salts than another, or might shade its neighbour by virtue of more rapid shoot growth. But the latter influence, which in fact could have been felt only by the slow growing *Cryptomeria* adjacent to the rapidly growing *Cupressus*, was reduced to the minimum by orienting the two species differently to one another in each of the three replications.

The following table shows the origin and harvest year of the seed used, the dates on which the crops were established by dibbling pregerminated seed into holes made by a specially constructed sowing board, and the periods in which the experiments were concluded by washing out the roots. For the coniferous seedlings the spacing of $2'' \times 2''$ proved sufficiently wide. But so rapid was the

TABLE I

<i>Species.</i>	<i>Origin and year of seed.</i>	<i>Sown.</i>	<i>Excavated.</i>
<i>Fraxinus excelsior</i>	Petersfield, Hants., 1930	Mar. 14-18	Sept. 24-Oct. 20
<i>Cupressus macrocarpa</i>	Monterey, California, 1930	May 5-7	Dec. 8-Jan. 20
<i>Cryptomeria japonica</i>	Chita forest, Japan, 1930		
<i>Picea excelsa</i>	Austria, 700-1,600 ft. alt., 1929	May 25-28	Nov. 10-Dec. 1
<i>Larix leptolepis</i>	Japan, 1930		

growth of those ash seedlings which received heavy doses of ammonium nitrate that a thinning became imperative, and on 15 July alternate plants were removed by cutting off the shoots 2 cm. below the cotyledons.

Losses were trifling among the ash, of which only nine of the original 1,344 plants died. But damping-off fungi reduced the number of larch to 16-31 per box, that of *Cryptomeria* to 19-29, of spruce to 25-32, and of *Cupressus* to 31-32. An effort was made to check these losses by watering the coniferous crops with a solution of 1 oz. per gallon of potassium permanganate on 4 June. All losses were made good by the introduction of substitute seedlings, which were marked, and discarded at the end of the experiment, after they had served their purpose by competing with their neighbours.

The nutrient salts were applied in dilute solution at frequent intervals, since they would be leached out rapidly from the porous sand so freely drained. Each box of plants received the following basal solution of B.D.H. A.R. salts during the course of the season:

KH_2PO_4	10 grammes.	$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	16 grammes.
$\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$	12 grammes.	FeCl_3	0.2 gramme.

It was calculated that such quantities of salts would yield so ample a supply of the contained essential nutrients that none of these would limit the growth of the plants.

Each species was subjected to seven different treatments as regards the quantity of NH_4NO_3 supplied, and there were three replications of every treatment. Since the conifers were grown together as above described, there were three boxes for each replication of a given treatment, and the total number of boxes used was thus $3 \times 7 \times 3 = 63$. During the season the boxes of the seven different treatments received the following quantities of NH_4NO_3 , which are equivalent to the underlying supplies of nitrogen per plant:

TABLE 2

NH_4NO_3 per box, grammes.		0	0.548	1.097	2.194	4.388	8.777	17.553
Nitrogen per plant in mg.	Conifers	0	3	6	12	24	48	96
	Ash, main crop	0	4.5	9	18	36	72	144
	Ash thinnings	0	1.5	3	6	12	24	48

The ash thinnings were removed when exactly half the nutrient solutions for the season had been applied. Thereafter the doses of nutrient solution were not reduced in accordance with the halving of the number of plants, because it was then evident that too low a range of doses of NH_4NO_3 had been supplied. Thus the ash thinnings received half the quantities of both basal solution and NH_4NO_3 allotted to the conifers, while the ash of the main crop enjoyed one and a half times as much. The quantity of the nutrient solutions was increased from a small quantity early in the season to a maximum in August, since the plants would be in a position to absorb more nutrient the greater the spread of their root systems. Owing to the differences in the dates of sowing and harvesting, the distribution of the nutrient solutions throughout the season differed in the several sets of plants. For the conifers the percentage distribution

per plant was the same as that per box, but for the ash the thinning affected the distribution of salts as shown hereunder. The several sets of plants received the following percentages of their total basal solution, and of their quota, according to treatment, of NH_4NO_3 , during the periods shown. In each of

TABLE 3

<i>Asb.</i>			<i>Cupressus and Cryptomeria.</i>	<i>Larch and Spruce.</i>
<i>per box.</i>	<i>per main crop plant.</i>	<i>per thinning.</i>		
Apr. 5%	3.3%	April. 10%		
May. 10%	6.6%	May. 20%	May 20-June 11. 5%	
June. 20%	13.3%	June. 40%	June 16-30. 10%	June 15-30. 5%
July. 30%	30.0%	July 1-15. 30%	July. 20%	July. 20%
Aug. 35%	46.7%		Aug. 35%	Aug. 40%
			Sept. 30%	Sept. 35%

the periods the salts were applied in five equal doses, evenly distributed over the period. Thus in each monthly period the interval between applications was 6 days, while in the shorter periods it was correspondingly shorter. Both basal solutions and ammonium nitrate were evenly distributed over the surface of the sand by applying them between the rows of plants through a pipette.

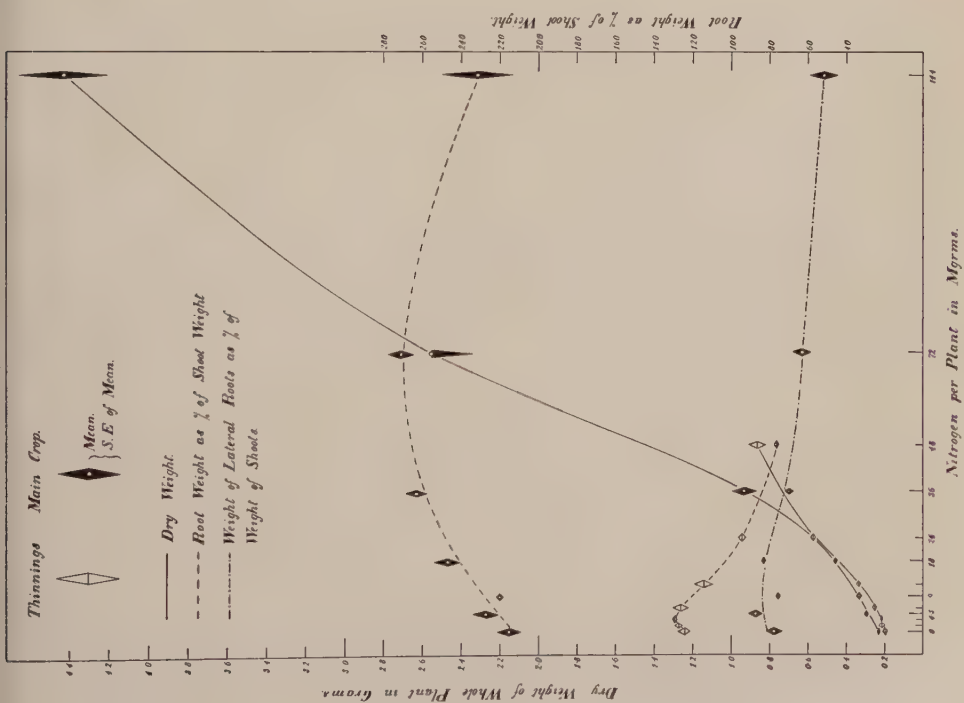
There was an extensive growth of algae in the superficial sand in those boxes receiving the heavier doses of ammonium nitrate, and this cemented layer of sand was frequently broken up to minimize the retention of nutrient salts by the algae. All the plants were heavily watered whenever necessary.

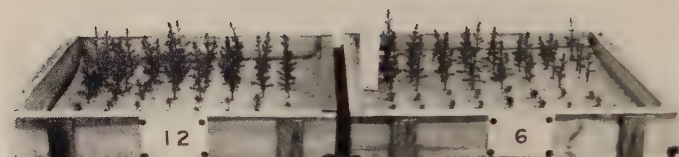
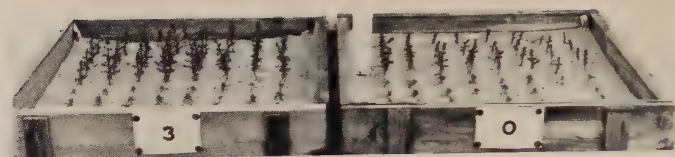
By 3 May the ash seedlings began to show the influence of ammonium nitrate, and by the end of that month they were clearly graded according to the quantity received. *Cupressus* first showed a reaction to treatment in the second week of June, and *Cryptomeria* responded in the last week of that month. Larch and spruce exhibited no effect until the second week of July.

Method of examining the plants.

The deciduous ash was of necessity excavated first; and, since some of these plants, especially those which had received little ammonium nitrate, began to lose their foliage at the end of September, all moribund leaves were then plucked off, and retained to be weighed with the plants when these were available. Larch needles began to fall early in November, and the shoots of the larch were then cut off. Thus accurate shoot weights were obtained for both the deciduous species. Unfortunately, owing to pressure of other work, there was not time to examine all the *Cupressus* and *Cryptomeria* seedlings, and attention was therefore confined to those which had received 1, 12, and 96 mg. of nitrogen.

Each box was carried by four men on a stretcher to a large open tank, half filled with water. The stretcher was placed across the top of this tank at a





Replication I of experiment on *Cupressus macrocarpa*, behind, and *Cryptomeria japonica*, in front.
The figures beneath the boxes show the amount of nitrogen in milligrams supplied per plant

The scale is 1 foot.

PLATE IV

small angle to the horizontal, so that the sand did not fall away when one side of the box was detached. Water was drawn from the tank in a watering-pot, and poured over the sand till all was removed. By this method the roots were obtained unbroken in a reasonably short time.

On arrival at the laboratory the shoots were severed from the roots, 2 cm. below the cotyledons in the case of ash, 1 cm. below the cotyledons in all the conifers. Notes were made on root branching. The last traces of sand were removed, roots and shoots were dried to constancy at 100–105° C., and the average weight per shoot or root was found by dividing the aggregate weight by the number of individuals. From these data the relative root weight and the average weight per plant were obtained. It was not feasible to weigh each shoot and root separately. Thus the standard errors attached to the means in the graphs and table refer to the variance due to replication, and not to the variance from plant to plant. The shoots of the ash thinnings removed in July had been weighed at the time, and their roots, left in the sand till the end of the experiment, showed no sign of decay. Reasonable confidence of accuracy can therefore be placed in the figures for the mean weight and relative root weight of these thinnings.

The data for the ash are shown graphically in Plate III, Fig. 1, those for larch and spruce in Fig. 2. Table 4 gives the more limited results for *Cupressus* and *Cryptomeria*, and Plate IV shows the condition of these plants in all treatments of replication 1 at the end of November.

TABLE 4

Nitrogen per plant in mg.		0	12	96
Mean weight of shoot in grammes	<i>Cupressus</i> <i>Cryptomeria</i>	0·046±0·006 0·014±0·001	0·298±0·006 0·035±0·006	1·558±0·100 0·104±0·005
Mean weight of root in grammes	<i>Cupressus</i> <i>Cryptomeria</i>	0·051±0·005 0·014±0·002	0·225±0·007 0·031±0·004	0·696±0·035 0·050±0·004
Mean weight of whole plant in grammes	<i>Cupressus</i> <i>Cryptomeria</i>	0·096±0·012 0·029±0·003	0·523±0·007 0·066±0·010	2·254±0·135 0·154±0·009
Root weight as per cent. of shoot weight	<i>Cupressus</i> <i>Cryptomeria</i>	113±5·8 101±2·7	76±3·3 90±4·6	45±0·7 47±2·3

Relation between the amount of ammonium nitrate and yield.

The yield curves show that the maximum dry weight was not secured in the case of ash, larch, and spruce, since the range of doses of NH_4NO_3 supplied was too low. From the limited data for *Cupressus* and *Cryptomeria* it is impossible to say whether heavier plants might have been obtained by giving them more than 96 mg. of nitrogen. The slow growth of *Cryptomeria* is remarkable, and it was thought that these plants might have suffered in root competition with the rapidly growing *Cupressus*. But the *Cryptomeria* plants which received 96 mg. of nitrogen were little smaller than plants of this species, sown earlier, growing in a manured nursery bed nearby. Thus it appears that much more

rapid growth in early life cannot be expected, at all events in climates drier than the tree's native home.

In the previous work (1) on Corsican pine seedlings the relation between the quantity of NH_4NO_3 supplied and the resulting dry weight of the seedlings was expressed by a curve of logarithmic type. Most of the recent work shows that the relation between the quantity of a growth promoting substance and the resulting yield should be expressed in this manner. Here, however, the yield curve for ash is sigmoid, and definitely exponential in the lower portion. The differences in the curves may none the less be explained. In the work on Corsican pine the nutrient solutions were retained in a watertight pot throughout the season, and were thus always available to the plants; while in the present experiment the nutrient salts were available to the plants only in so far as they could absorb them during a single percolation through the sand, and the quantity given during the first two months was only ten per cent. of the whole. Thus a plant of the final crop, supplied with the equivalent of 9 mg. of nitrogen in the whole season, received only 0.9 mg. in April and May. Its limited root system probably secured a smaller proportion of the subsequent doses than did the more extensive one of a plant which had been given 10 per cent. of 72, i.e. 7.2 mg. of nitrogen, in those first two months.

The data for larch and spruce are perplexing, and no reasonable explanation for the dip in the curves in the central region can be advanced. But the results for larch, at least, may be unreliable, since the variance in size of individual plants within a given treatment greatly exceeded the differences due to treatment.

The influence of ammonium nitrate on relative root weight.

In early life ash almost conforms to the more general rule that relative root weight decreases with the amount of available nitrogen. But in this species, contrary to Meyer's (7) and Rippel and Ludwig's (12) findings for oats and *Helianthus* respectively, the relative root weight increased very markedly with increase in age; and at the end of the season it was higher in plants receiving a moderate supply of ammonium nitrate than in those to which none or much of this nutrient had been given. However, it was suspected that much of this increase in root weight was accounted for by the great thickening of the radicle, and accordingly, in replications 2 and 3 of the final crop, the lateral roots were weighed separately, and their weight was expressed as a percentage of the weight of the shoots in the lowermost curve of Fig. 1. Thus plants receiving much ammonium nitrate had a smaller proportion of their substance actively devoted to absorption than those receiving little or none of this salt. Therefore, even in this species, it may be that the 'balance' is less favourable the greater the supply of ammonium nitrate.

The relative root weight of larch fell with increase in the supply of ammonium nitrate, and that of spruce followed the same tendency, after a significant increase resulting from small applications of this nutrient. *Cupressus* and *Cryptomeria* evidently follow the general rule.

As a result of experiments with representatives of five genera of conifers, *Pinus*, *Larix*, *Picea*, *Cupressus*, and *Cryptomeria*, we may conclude that the majority of coniferous tree seedlings will respond to heavy application of nitrogenous manures by a decrease in relative root weight. For hardwood trees, however, it is unsafe to attempt a generalization of our present limited knowledge for ash and *Casuarina equisetifolia*.

Root branching.

There was not time to obtain an accurate assessment of the density of root branching by finding the root quotient, i.e. the ratio 'root length/number of root tips'. Corsican pine seedlings had a less densely branched root system the greater the supply of NH_4NO_3 ; in other words, their root quotient became larger. It is thought that all the species grown in 1931 followed this rule. For, although branches of higher order were present on plants receiving much than on those receiving little NH_4NO_3 , the branches of each order were longer the greater the supply of this nutrient.

All the radicles of the ash plants of the final crop reached the base of the box, and some grew horizontally along it for a short distance. Those of plants which had been given 144 mg. of nitrogen attained a maximum diameter of 9 mm. There was a region half-way down the box in which the development of the lateral roots was restricted, due apparently to the comparative dryness of the sand at this level. In those plants receiving little or no nitrogen the lateral roots were best developed near ground-level, while in those receiving much, the greatest development was near the base of the box. Secondaries were numerous on all plants, and varied in maximum length from 12 cm. on plants receiving no nitrogen to 30 cm. on those receiving 144 mg. thereof. Tertiaries were scarce on plants receiving no nitrogen, but numerous on all the remainder. Branches of the fourth order were present only on plants receiving 18 mg. or more of nitrogen, and on none were they numerous. Root hairs were poorly developed, and no mycorrhizal infection was observed.

Radicles of the larch attained a maximum length of 44 cm., and in all treatments many of them reached the base of the box. Secondaries were spaced far apart on the radicle; they varied in maximum length from 15 cm. on the plants receiving no nitrogen to 38 cm. on those receiving 96 mg. of this nutrient. Tertiaries were scarce on the plants deprived of nitrogen, and were numerous only on those receiving the heaviest dose thereof. Root hairs were poorly developed, and mycorrhiza was absent.

A few of the spruce radicles attained a length of 40 cm. in all treatments, and the maximum length recorded was 44 cm. on a plant receiving 96 mg. of nitrogen. This shows that spruce seedlings can be quite deep rooted if grown in a well-aerated medium. It is true that many of the radicles were only 25 cm. long, but all were alive at the tip. The secondaries were more numerous than on the larch, and they were shorter, reaching a maximum length of 16 cm. on plants deprived of nitrogen, and of 24 cm. on those receiving the heaviest application. They were densely covered with tertiary roots; but these were

short, and quaternaries, though present on all plants, were numerous on none. All parts of the root system were densely clad in long root hairs, and, as a result, it was very difficult to remove the last traces of sand from roots of this species. There was no mycorrhizal infection.

The radicle of all the *Cupressus* seedlings reached the base of the box, and the maximum length recorded was 64 cm. for a plant receiving 96 mg. of nitrogen. Secondaries were moderately plentiful, and varied in maximum length from 26 cm. on a plant receiving no nitrogen to 47 cm. on one receiving 96 mg. thereof. Tertiaries were numerous on all plants save those deprived of nitrogen; but despite their considerable length they bore very few quaternaries. In fact, such roots were present only on plants receiving 96 mg. of nitrogen. No root hairs were seen, and mycorrhiza was absent.

Root development was feeble in all the *Cryptomeria* plants. The radicle varied in maximum length from 37 cm. on a plant deprived of nitrogen to 42 cm. on one receiving 96 mg. of this nutrient, but the average length was about 25 cm. in all treatments. Secondaries were few and short, attaining a maximum length of 25 cm. on a plant receiving the heaviest application of NH_4NO_3 . Tertiaries were absent from the majority of plants receiving no nitrogen, and on no plants were they numerous. There were no quaternaries, no root hairs, and no mycorrhiza.

Thus root development was distinctly extensive in ash, larch, and *Cupressus*. For the spread of the root system was considerable; but the large volume of sand penetrated was not thoroughly permeated with fine branch roots, and root hairs were absent or poorly developed. The feeble *Cryptomeria* root system might also be classified as extensive. In sharp contrast the intensive root system of spruce permeated a smaller volume of sand much more thoroughly.

THE EFFECT OF SUGAR ON THE DEVELOPMENT OF SEEDLINGS

Reid (9) quotes Godlewski (4) for the assertion that barley seedlings are stimulated in their relative root growth by the addition of sugar to a mineral nutrient solution devoid of nitrogen. There could be no value in producing small seedlings with a still higher relative root weight than those grown without nitrogen. But it might be very valuable if we could learn a technique for growing large seedlings with relatively heavy roots. And it appeared possible that seedlings of this desirable type might be produced if they were given an ample supply of all essential mineral nutrients plus sugar. Accordingly an effort was made to increase the relative root weight of seedlings of Corsican pine, *Pinus laricio*, Poir. var. *corsicana* Loud., and *Cupressus macrocarpa* Hartw. by growing them in a rich mineral solution with the addition of sucrose.

Method of growing the plants.

Seedlings of these two species were grown in quartz sand in glazed earthenware pots of internal dimensions 13 inches diameter and 18 inches deep. Thirty-two pregerminated Corsican pine seeds of the 1930 Corsican harvest

were established at an espacement of $1\frac{1}{8}$ inches in each of six pots on 23 May, and on 25 May six pots were similarly sown with *Cupressus macrocarpa* seed of the 1930 Monterey harvest. Each set of six pots was housed in a glazed frame so constructed that, when open, it cast no shadow on the plants. These frames were closed only at night and during rain.

The water table was maintained at a constant level of 4 inches from the base of the pot by the method employed in the previous work on Corsican pine. But the plants were watered by a new method, by which the superficial layer of sand was kept dry and free from algal growth. The nutrient solution was drawn off into a wash bottle, and distributed therefrom into twenty-one glass tubes, 2 inches long and $\frac{1}{2}$ inch in diameter, which were sunk $1\frac{1}{2}$ inches at an equal espacement over the surface of the sand. A piece of fine muslin over the lower mouth of these tubes prevented the sand from rising into them.

Each pot of both species received the following basal solution of B.D.H. A.R. salts, half of which was applied on 29 June and half on 1 August:

KH_2PO_4	5 grammes.	$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	8 grammes.
$\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$	6 grammes.	FeCl_3	0.1 gramme.
NH_4NO_3		5 grammes.	

These quantities are the same as those applied per pot of fifty-two Corsican pine seedlings receiving the heaviest dose of NH_4NO_3 in 1929, and each seedling thus received considerably more than those seedlings, which apparently failed to attain the maximum possible weight. In addition three pots of Corsican pine and three of *Cupressus* each received 16 grammes of sucrose, equivalent to 0.5 gramme of this sugar per plant. Half of this was applied on 29 June and half on 1 August.

Heavy losses were sustained by the Corsican pine, but few of the *Cupressus* seedlings died. All dead plants were replaced by substitutes, which were discarded at the end of the experiment.

The *Cupressus* seedlings were excavated on 26 and 27 October, and the Corsican pine seedlings on 29 and 30 October. Shoots of the *Cupressus* and Corsican pine seedlings were severed from the roots 1 cm. and 2 cm. below the cotyledons respectively, and shoots and roots were dried to constancy at $100\text{--}105^\circ\text{C}$.

Results.

The mean results are shown in Table 5, with the standard errors for the variance due to replication.

Thus, in the quantity used, sucrose had no influence on the weight of seedlings of either species. In both species the relative root weight was higher in the plants receiving sucrose, but the differences were not sufficiently significant to warrant a definite conclusion. The root quotients were not determined, but casual inspection revealed no obvious influence of sucrose on root branching.

It may be that a larger or smaller dose of sucrose, or an application of another kind of sugar, would prove more effective. Godlewski's (4) original paper was

TABLE 5

		<i>With sucrose.</i>	<i>Without sucrose.</i>	<i>Probability of significance of difference.</i>
Mean weight of whole plant in grammes	<i>Cupressus macrocarpa</i>	0.966 ± 0.085	0.983 ± 0.109	1 to 1
	Corsican pine	0.804 ± 0.034	0.813 ± 0.010	1 to 1
Root weight as per cent. of shoot weight	<i>Cupressus macrocarpa</i>	36 ± 0.9	34 ± 1.2	12 to 1
	Corsican pine	71 ± 2.3	66 ± 1.5	10 to 1

not accessible to the writer, who does not know what sugar he used in his work on barley seedlings.

THE EFFECT OF SUPERNORMAL CO₂ SUPPLY ON THE DEVELOPMENT OF CORSICAN PINE SEEDLINGS

Reid (11) found that wheat seedlings grown without CO₂ had a lower relative root weight than those grown in an atmosphere containing 0.04 per cent. of CO₂ by volume. It appeared possible that heavy seedlings with relatively heavy roots might be produced by giving them plenty of all the essential mineral nutrients plus a supernormal supply of CO₂. Corsican pine was chosen for this experiment, as the species about which most was then known.

Technique of the experiment.

For this experiment there were used six glazed earthenware pots of internal dimensions 9½ inches diameter and 18 inches deep, with the upper flange ground to fit the flange of a bell-jar. These were filled to the brim with sieved quartz sand, and on 25 May nineteen pregerminated Corsican pine seeds were sown in each pot at an espacement of 1¾ inches. Each pot received a nutrient solution containing $\frac{19}{32}$ of the weight of KH₂PO₄, MgSO₄·7H₂O, CaCl₂·6H₂O, FeCl₃, and NH₄NO₃ supplied per pot in the experiment on the influence of sucrose, and the quantity of mineral nutrients available to each plant was thus identical in the two experiments. Half of this solution was applied on 30 June and half on 11 August. The watering arrangements were the same as those in the experiment on sucrose, and the pots were housed in a similar frame.

In periods of bright sunshine the atmosphere around the seedlings in three of the pots was enriched by placing bell-jars of 11.5 litres capacity over the pots, and aspirating 0.096 gramme of CO₂ into each jar from an external generator, in which this gas was made by the action of 0.158 gramme of HCl (5 c.cm. of sp.gr. 1.015) on slightly over the equivalent of pure CaCO₃. The introduction of this quantity of gas brought the CO₂ content of the air in the bell-jar up to about sixteen times normal. A higher concentration might have damaged the plants. Yet calculations showed that this amount of CO₂ was

only about thrice the amount which nineteen Corsican pine seedlings might normally use in an hour, and each treatment was therefore limited to one hour. Meanwhile the control plants were covered with similar bell-jars, in order to subject them to similar conditions of light and humidity; and they must have suffered from a subnormal supply of CO_2 . It was not possible to be out at Kennington all day and every day. And, since there was comparatively little sunshine in 1931, the plants received only 135 hourly doses, ten between 11 and 31 July, thirty in August, forty-one in September, and fifty-four in October.

On 4 and 5 November the seedlings were excavated, and dealt with in the same manner as those in the experiment on sucrose.

Results.

The mean results are shown in Table 6, with the standard errors for the variance due to replication. There was no obvious effect of CO_2 on root branching.

TABLE 6

	<i>With</i> CO_2 .	<i>Without</i> CO_2 .	<i>Probability of significance of difference.</i>
Mean weight of whole plant in grammes	0.745 ± 0.040	0.690 ± 0.009	2 to 1
Root weight as per cent. of shoot weight	69 ± 2.1	67 ± 2.9	1 to 1

Thus this experiment also gave disappointing results. Yet the relative root weight was slightly higher in the plants receiving CO_2 , and it is possible that a significant effect might be produced by more frequent application of CO_2 in a sunnier season.

DISCUSSION

We now know that seedlings of most conifers, and of at least one broad-leaved tree, respond to increase in the supply of nitrogen by a decrease of relative root weight. There are indications that phosphates and potash may similarly depress relative root weight, but as yet we have no data from sand-culture experiments with forest-tree seedlings. No success has attended efforts to produce a large seedling with a relatively heavy root by giving it a plentiful supply of mineral nutrients plus a supernormal supply of carbohydrates. But we know from Shirley's (13) work that coniferous seedlings respond to shading by a decrease of relative root weight; and from this fact we draw the moral that shading of seed beds should be reduced to the necessary minimum.

It has been tacitly assumed that a plant with a relatively light root will be less drought resistant and less tolerant of moving than a plant with a relatively heavy root. But drought resistance depends on many factors, and there is no definite proof that our assumption is correct. For afforestation of sites

which are not liable to be drought ridden a large plant with a relatively light root may suffice, and it may be that plants destined for such sites should be heavily manured in the nursery.

From the practical standpoint the best criterion of the drought resistance of nursery stock is the percentage survival of such stock when it is transplanted or planted out in the forest. The value of manurial treatments in the nursery should therefore be assessed by their influence on the survival and growth of plants after moving.

Heartiest thanks are due to Mr. Gray and his assistants for help at Kennington nursery; to Mr. Shaw for tracing the graphs; and to Mr. Clinkard for taking the photographs.

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THE FORM OF THE STEM IN CONIFEROUS TREES

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INTRODUCTION

ONE of the main objects of forest mensuration is the determination of the volume of trees. Normally, volume can only be found indirectly, as a result of the determination of the following factors, the length or height, the sectional area at the base or at breast height, and the form or taper; and in consequence the accurate measurement of height, of sectional area, and of form becomes of the first importance. The measurement of the length of a log or the height of a standing tree does not as a rule present any difficulty, nor does the calculation of the sectional area at breast height; but to obtain an accurate measure of the third factor has always proved an awkward problem.

It is well known that individual trees vary greatly in the rate at which their stems taper from base to tip. If, for example, we were to select from a plantation two trees of the same species with the same breast-height girth and the same height, we should probably discover that their volumes were quite different; this difference, since the other factors were constant, would be due to difference in form. The tree with the more rapid taper would show the lower volume, and that with the better form would show a correspondingly higher content. It is obvious, therefore, that the mensuration of form is of as great importance as that of height and breast height diameter or girth.

If we divide the volume of a tree by that of a geometrical solid (a cylinder), with the same basal area and the same height we obtain an expression which is known as the *form-factor*. This form-factor normally has a value less than unity.

When height, basal area, and form-factor are known then the volume is obtained by the following formula:

$$V = shf,$$

and form-factors have thus been extensively used in mensuration as an aid in the determination of volumes.

Different kinds of form-factors have been proposed. The *absolute* form-factor is the ratio between the volume of a tree and the volume of a cylinder with the same height and the same diameter or girth at the base. This form-factor has not been extensively used as there is always a difficulty in measuring the girth or diameter at ground-level, while such diameters, once obtained, generally prove to be abnormally high owing to the presence of root-swelling and buttresses.

This difficulty was overcome in the common *breast-height* form-factor which represents the ratio between the volume of the tree and that of a cylinder with the same height and the same girth or diameter as that of the tree at breast height. This is the form-factor which is in general use. As a guide to the form

or taper of a stem, the breast-height form-factor is useless. Since breast height is a constant for trees of all heights, the proportion which it bears to the total height must vary according to that height; on small trees it is relatively near the tip, while on tall trees it is relatively much farther distant. Thus two trees with the same girth and stem-form but with different heights will certainly have different breast-height form-factors.

The *normal* form-factor proposed by Pressler aimed at avoiding the disadvantage which is inherent in the breast-height form-factor. For the normal form-factor the sectional area for comparison is taken at a point on each tree chosen so as to represent a fixed proportion of the total height. The proportion generally taken was one-twentieth. Form-factors of this kind gave a fair idea of the form, but they proved exceedingly difficult to work in practice.

Riniker's *absolute form-factor* was introduced in 1873 by Hans Riniker (16) in Switzerland. This form-factor deals with that part of the stem above breast height only, and is the ratio between the volume of the stem above the point of measurement and the volume of a cylinder on the breast-height basal area and with the same height as the portion of the tree above breast height. Riniker's form-factor, long neglected, has now come into greater prominence in connexion with recent work; it gives a value independent of height and girth.

As we have seen, the form-factor as an expression of stem-form is either inaccurate or inconvenient in use, and this has long been realized. No marked advance, however, was made until 1905, when Schiffl (17) introduced a new conception—the *form-quotient*—which was obtained by dividing the diameter at the mid-point of the stem by the diameter at breast height. Schiffl found that trees with the same form-quotient and the same height had the same rate of taper independent of the diameter, and this was confirmed by Maass (12).

The chief objection to Schiffl's form-quotient was substantially the same as that which has been advanced against the breast-height form-factor. The form, though independent of the diameter, is not independent of the height. This was put right by Jonson, who in 1910 (8) proposed that the upper diameter should be measured, not at the mid-point of the stem, but at the mid-point of that part of the stem which is above breast height. This new quotient he called the *absolute form-quotient*. The trees were then grouped according to their form-quotients into *form-classes*; all trees with form-quotients of 0.600 were placed in *form-class* 60.0, and similarly for the other values.

Jonson's earliest work was carried out on Norway spruce, and for this species he found that in trees of the same form-class the taper or form is independent not only of diameter but also of height. Trees with the same absolute form-quotient, irrespective of their size, are built upon the same lines. Jonson's next step was to find a formula which would express the taper of the stems in the Norway spruce, and he adopted a formula which had been developed in 1903 by the Swedish engineer, A. G. Höjer (7). This formula can be expressed in the following way:

$$\frac{d}{D} = C \log \frac{c+l}{c},$$

where D is the diameter at breast height and d the diameter at a point on the stem at a percentage distance l from the tip. C and c are constants which vary for each form-class. This formula can be used to obtain the diameter at any point on the stem once the form-class and breast-height diameter are known, and the following table gives for different form-classes the diameters at various points on the stem expressed as percentages of the breast-height diameter:

$$\frac{d}{D} = C \log \frac{c+l}{c}$$

Form- class.	Diameter as a percentage of breast-height diameter at								
	10	20	30	40	50	60	70	80	90
	percentage of the stem above breast height.								
60.0	93.0	85.5	77.6	69.1	60.0	50.1	39.4	27.7	14.6
65.0	94.2	87.8	80.9	73.4	65.0	55.6	45.0	32.7	18.0
70.0	95.2	89.9	84.0	77.5	70.0	61.4	51.3	38.8	22.7
75.0	96.1	91.7	86.9	81.4	75.0	67.5	58.2	46.3	29.3
80.0	96.9	93.5	89.6	85.1	80.0	73.7	65.8	55.2	38.7

In a later paper Jonson (9) dealt with Scots pine, but with this species he found that while the actual measured values under bark agreed fairly well with the theoretical values in the lower part of the stem, they were considerably less in the part of the tree near the tip. He therefore modified his formula slightly for this species by introducing a 'biologic' constant as follows:

$$\frac{d}{D} = C \log \frac{c+l-2.5}{c}$$

This new constant introduced slight changes into the quotients for the lower parts of the stem and much greater changes in the values at 80 and 90 per cent. from breast height.

For comparison with the preceding table, the same diameter percentages calculated with the modified formula are given below:

$$\frac{d}{D} = C \log \frac{c+l-2.5}{c}$$

Form- class.	Diameter as a percentage of breast-height diameter at								
	10	20	30	40	50	60	70	80	90
	percentage of the stem above breast height.								
60.0	93.1	85.7	77.8	69.3	60.0	49.9	38.7	26.0	12.0
65.0	94.3	88.0	81.1	73.5	65.0	55.4	44.3	31.1	15.0
70.0	95.3	90.0	84.1	77.5	70.0	61.1	50.6	37.2	19.4
75.0	96.2	91.9	87.0	81.5	75.0	67.3	57.6	44.8	25.6
80.0	97.0	93.6	89.7	85.2	80.0	73.6	65.4	53.9	34.7

It has been stated that the form of the stem under bark in the Scots pine was found to agree fairly well with the theoretical values. If, however, the diameters are measured over bark in this species, the agreement is poor, and the

form-class obtained from the over-bark measurements is not the same as that given by the under-bark data. This is caused by the variations in bark thickness at different points on the stem and by the great variations in bark thickness in individual trees. Norway spruce, on the other hand, has a fairly constant bark thickness, and the form over bark does not differ markedly from the under-bark form.

Another factor which caused the actual measurements to differ from the theoretical values is the root-swelling which extends from the ground-level upwards on the stem. Root-swelling is present to a greater or less degree on all trees, but it affects the form-class measurements only when it extends as far as breast height. If the breast-height diameter is abnormally increased by root-swelling, the form-class will have too low a value. The effect of root-swelling fortunately can be eliminated by a graphical method as will be shown later.

Jonson's work meant a great advance in two directions. With his absolute form-quotient he established a measure of form which was independent of height and size, and with his stem curves he was able to show that trees of different species have substantially the same form under bark.

Continuing Jonson's work, Matsson (14) investigated the form of the European and Siberian larches, and found that the form of the stem in these species could also be represented by Jonson's formula for Scots pine. This was another step forward.

After the war considerable attention was paid to the Swedish work by foresters in the United States and in Canada. The earlier investigations, such as those by Claughton-Wallin and McVicker (5), Wickenden (20), Wright (21), and Behre (2), consisted of attempts to fit the taper of numerous species to Höjer's theoretical curves. The writers first mentioned dealt with red pine, white pine, and white spruce in eastern Canada, and with a variety of conifers in British Columbia. They found good agreement with Jonson's Scots pine curve once root-swelling had been eliminated, but the conformity was most complete in the lower parts of the stem, considerable deviations occurring in the portion next the tip, particularly in young trees. As for the western species, there was satisfactory agreement with the theoretical curves, after root-swelling had been allowed for. Wright, in 1923, published a paper in which he gave the results of his investigations in Canada of 5,000 trees belonging to eight different species; in this he came to the conclusion that form-class varied with species, diameter, and age, and that a general formula was inapplicable. His conclusions were criticized by Baker (1) and by Behre (3), who both showed that had Wright taken root-swelling into account he would have found his species conforming to the general type. In a much fuller treatment of the subject published in 1927, Wright (22) maintained his earlier position to all intents and purposes unchanged.

The most important of the earlier papers in America was that published in 1923 by Behre (2) who had carried out an examination of the stems of a number of western yellow pine. This author found that when root-swelling had been

eliminated, the conformity to Höjer's formula was very good in the lower form-classes, but not so good with trees of fuller form, for he found that in form-class 80·0, a 'biologic' constant of 7·5 would have been required to give complete conformity. Behre proposed in view of the discrepancies which had been noticed both by himself and by other workers that a new equation should be adopted as an expression of stem-form.

This equation is written

$$\frac{d}{D} = \frac{l}{a+bl'}$$

where d , D , and l have the same meaning as in Höjer's equation, and a and b are constants varying for each form-class, or generally

$$y = \frac{x}{a+bx}$$

This equation was found to fit the European species as well as most of the American conifers, including *Sequoia* (18). The only tree which showed a wide divergence from the formula was the eastern hemlock spruce.

From this formula a set of curves was derived to express the theoretical taper in each form-class. The diameters at various points on the stem, expressed as percentages of the breast-height diameter in accordance with this formula, are given for a few of the form-classes in the following table:

$$y = \frac{x}{a+bx}$$

Form-class.	Diameter as a percentage of breast-height diameter at								
	10	20	30	40	50	60	70	80	90
	percentage of the stem above breast height.								
60·0	93·1	85·72	77·78	69·23	60·00	50·00	39·13	27·27	14·29
65·0	94·36	88·13	81·24	73·58	65·00	55·32	44·31	31·71	17·11
70·0	95·45	90·32	84·48	77·78	70·00	60·86	50·00	36·84	20·59
75·0	96·43	92·30	87·50	81·82	75·00	66·67	56·25	42·85	25·00
80·0	97·30	94·12	90·32	85·71	80·00	72·73	63·16	50·00	30·77

On comparing these values with those given by Jonson for Scots pine, one finds that the differences are not very great and are confined chiefly to the upper parts of the stem. A full account of Behre's work and methods will be found in his paper published in 1927 (4).

Concurrently with this American work, investigations were being continued in Europe, chiefly in Scandinavia. Many of these had to do with methods of determining the form-class, a subject which will be discussed later, but several dealt with the representation of stem-form by means of mathematical expressions. The most important of those was that described by Petterson (15) in a publication which appeared in 1926. In this paper Petterson recommended the logarithmic curve

$$y = \log x$$

as an expression of the form of the stem. By this method a series of curves,

one for each form-class, would be no longer necessary, and the different form-classes would be given by different parts of this curve. Petterson's method was criticized by Jonson (10) on the grounds of its inaccuracy in practice, and it is not now likely to have any great influence. Other equations have been proposed by Langsaeter (11), Tiren (19), and Heijbel (6), and there would seem to be no difficulty in fitting many more to the data which have been obtained.

We have seen that the stems of a great number of coniferous species have been found to possess substantially the same form under bark, and that this form can be expressed mathematically by a variety of equations of which the most convenient are the Höjer-Jonson and the Behre. This knowledge has placed a new and powerful weapon in the hands of the forester.

INVESTIGATIONS IN GREAT BRITAIN

History and objects. Studies of stem-form have been going on in this country since 1923. The work, which has been carried out by the sample-plot staff

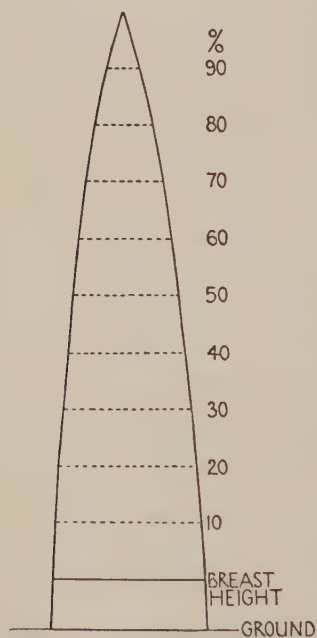


FIG. 1. The Points of Measurement on the Stem.

of the Forestry Commission, has consisted chiefly of form-quotient measurements of sample trees in the various permanent plots, but these have from time to time been supplemented by the measurement of groups of trees of peculiar interest, and on three occasions by complete measurements of all the trees in a felled plot. Few attempts have been made to go beyond the sample plots for material, and consequently the number of trees actually measured is probably smaller than the numbers dealt with by workers in other countries. On the other hand, however, the species which have been investigated are probably more numerous than is usual in European researches.

There were several immediate objects in taking up the study of stem-form. In the first place, it was necessary to determine whether conifers in Great Britain conformed to the same rules as those on the continent of Europe and in America; that is, whether the form of the stem could be expressed in this country also, by formulae such as Höjer's and Behre's.

Secondly, provided that the various species conformed satisfactorily, it was felt that form-class volume tables should be constructed for conifers in Great Britain whenever sufficient data could be brought together. The third object in view was the determination of a method of measuring sample trees standing; and the fourth, the investigation of the bark thicknesses in the various species.

The first of these objects is the principal concern of this paper, and in succeeding sections the actual form of the various species will be discussed. If the data permit, the second and fourth objects—volume tables and bark thicknesses—will also be dealt with; the third object—the measurement of standing trees—has already been treated elsewhere (13).

Field measurements. The measurements necessary on felled trees are simple. We measure the girth at breast height, and at each tenth of the length between breast height and the tip of the tree. The girths are taken both over and under bark and are read to the nearest quarter-inch. Occasional readings are taken of girths below breast height, but this is not the standard practice.

Example: If we have a tree with a total height of $64\frac{1}{4}$ ft., then the length of stem between breast height and the tip is 60 ft. The girths are taken in this case at intervals of 6 ft. along the stem between breast height and the tip—at 6 ft., 12 ft., 18 ft., and so on above breast height or at $10\frac{1}{4}$ ft., $16\frac{1}{4}$ ft., $22\frac{1}{4}$ ft., &c., from the root cut. (Fig. 1).

The various girths are entered on the field work sheet.

Office calculations. This is illustrated by an example.

Tree No. 70. Norway spruce. Fifty-five years old.

	Breast height.	Girths at percentages of stem length above breast height.								
		10	20	30	40	50	60	70	80	90
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
Girth over bark .	$29\frac{1}{2}$	$26\frac{3}{4}$	$25\frac{1}{2}$	24	$21\frac{1}{2}$	$19\frac{3}{4}$	$17\frac{1}{4}$	$13\frac{3}{4}$	10	$4\frac{1}{2}$
„ under bark .	$28\frac{1}{4}$	$25\frac{3}{4}$	$24\frac{1}{2}$	23	$20\frac{3}{4}$	19	$16\frac{1}{2}$	13	$9\frac{1}{2}$	$4\frac{1}{4}$
Bark per cent. .	$4\frac{1}{2}$	$3\frac{1}{2}$	4	4	$3\frac{1}{2}$	4	$4\frac{1}{2}$	$5\frac{1}{2}$	$5\frac{1}{2}$	$5\frac{1}{2}$

The first step is to work out the bark percentages at the various points of measurement on the stem as has been shown. The next step is to obtain the *girth-quotients* by dividing each of the under-bark girth measurements at 10 per cent., 20 per cent., &c., on the stem by the under-bark girth at breast height.

The following values are obtained in this example:

Percentage heights	10	20	30	40	50	60	70	80	90
Girth-quotients .	0.902	0.868	0.814	0.735	0.673	0.584	0.460	0.336	0.150

These girth-quotients are plotted against the corresponding height-quotients and a smooth curve drawn through the points (Fig. 2). This curve does not pass through the origin, thus indicating the presence of root-swelling. Actually it cuts the origin at the point $x = 0.933$. Thus we have

$$\begin{aligned}
 &\frac{\text{Normal B.H. Girth}}{\text{Actual B.H. Girth}} = 0.933 \\
 \therefore \text{Normal B.H. Girth} &= \text{Actual B.H. Girth} \times 0.933 \\
 &= 28\frac{1}{4} \times 0.933 \\
 &= 26.36 \text{ in.}
 \end{aligned}$$

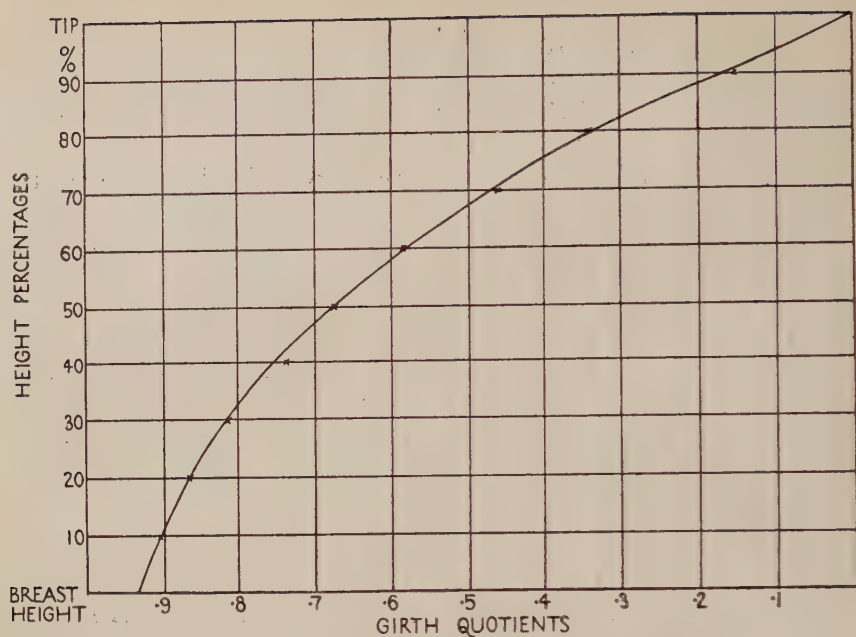


FIG. 2. Stem Curve before elimination of Root-swelling.

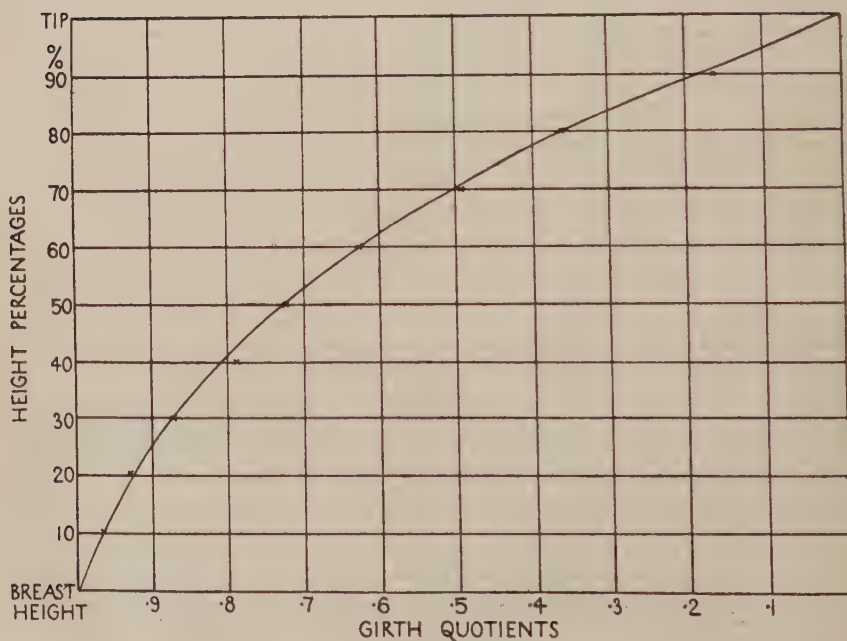


FIG. 3. Stem Curve—Root-swelling eliminated.

The various girths at the different points of measurement are divided again, but by the new normal breast-height girth, and a fresh series of values is obtained.

Root-swelling eliminated.

Percentage heights	10	20	30	40	50	60	70	80	90
Girth-quotients	0.977	0.930	0.872	0.788	0.721	0.626	0.493	0.360	0.161

These quotients are plotted as before against the corresponding height percentages, and a curve is obtained which passes through the origin (Fig. 3). This curve cuts the line representing 50 per cent. of the height above breast height at a point $x = 0.725$. The form-class is therefore 72.5.

This calculation is carried out for all trees. When there is no root-swelling the curve first drawn will pass through the origin and no further computation is required. The amount of the root-swelling is generally expressed as a fraction

$$\frac{\text{Actual B.H. Girth}}{\text{Normal B.H. Girth}}$$

In this case, this value is 1.072.

The trees are then grouped together into the different form-classes.

MATERIAL

The material used in the present study is given in the following table:

Species.	Number of trees.
Norway spruce (<i>Picea excelsa</i> Link.)	410
Sitka spruce (<i>P. sitchensis</i> Trautv. and Mey.)	242
Douglas fir (<i>Pseudotsuga taxifolia</i> Britt.)	494
European larch (<i>Larix decidua</i> Mill.)	521
Japanese larch (<i>L. leptolepis</i> Murr.)	195
Hybrid larch (<i>L. eurolepis</i> A. Henry)	10
Western larch (<i>L. occidentalis</i> Nutt.)	10
Scots pine (<i>Pinus sylvestris</i> L.)	390
Corsican pine (<i>P. laricio</i> Poir.)	113
Weymouth pine (<i>P. strobus</i> L.)	20
Western red cedar (<i>Thuja plicata</i> D. Don.)	33
Western hemlock (<i>Tsuga heterophylla</i> Sarg.)	18
(<i>Abies nobilis</i> Lindl.)	11
(<i>A. grandis</i> Lindl.)	23
Total	2,490

These are all trees which have been completely measured at every tenth of the length of the stem between breast height, and the tip. There are available numerous other measurements less complete, particularly of Douglas fir.

PLAN OF WORK

In an article in the next issue the under-bark stem-form of the various conifers will be discussed with reference specially to the Höjer-Jonson and the Behre

equations. Succeeding articles will deal with the variations in form within species and within stands, with mean form-class and methods of its determination, with bark thickness, with root-swelling, and with volume tables.

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THE WEDGE SYSTEM IN BADEN

BY W. L. MARJORIBANKS

ALTHOUGH the wedge system of natural regeneration has only really come into use since the War, it is already applied successfully over large areas in Baden. This being so, it is rather strange that the system is not fully understood in this country. The idea seems to exist that it is merely a shelter-wood system in which the successive regeneration fellings are made in the form of wedges pointing into the prevailing wind; this, however, is not a correct description of the system. For these reasons a short account of the procedure in Baden at the present day may be of interest to British foresters. The main idea behind the system is clear enough—that the wedge is the only form in which the old timber may be removed without danger from climatic agencies, especially wind.

To describe the procedure let us take as an example the regeneration of a compartment in the mountain coniferous type of forest, a stand of silver fir, Scots pine, and spruce, 100 years old. At distances of 80 metres, extraction lines 2 metres broad are cut across the compartment from east to west. Between those lines the centre lines of the wedges are marked by white rings on the trees. Starting from the north-east corner of the compartment, light regeneration fellings are made, particularly with a view to the removal of the smaller trees and the lower story. These light cuttings, or 'ticklings', as the Germans call them, are made over an area called a zone, which is in the form of a wide strip pointing north-west and south-east. Since these fellings are repeated at least every two years, the zone travels gradually across the compartment towards the south-west, i.e. the cuttings are made against the direction of the most dangerous winds. It must be borne in mind that wedges have not yet been opened. As a result of these fellings, regeneration of the shade-bearing species is obtained, first of silver fir and then of spruce. These species, especially the fir, are not so susceptible to damage during felling as the pine; moreover they need protection, and must be well established before the advent of the young light-demanders, else suppression and a pure stand of pine will result.

When satisfactory regeneration of the shade-bearing species has been obtained and is well established, a wedge-shaped clear-felling is started at the east end of the northernmost centre line. It is now that the regeneration of pine and other light-demanding species takes place, seed blowing in from the side into the area of the wedge. The prolific seeding properties of the pine effectively sow up any blank areas and all spaces between the young silver fir and spruce. Any other species desired are now brought in by planting, small seed-beds having been laid out beforehand on the centre lines of the wedges. A wedge is then started on the neighbouring centre line to the south, and so on. Thus, although each wedge points westwards, the whole series of wedges faces

the south-west winds, for the series moves diagonally westward led by the northernmost wedge, following behind the 'tickled' area or zone. The question might be asked why the wedges are not made to point south-west, that being the dangerous quarter; north-west winds, however, have also to be taken into account.

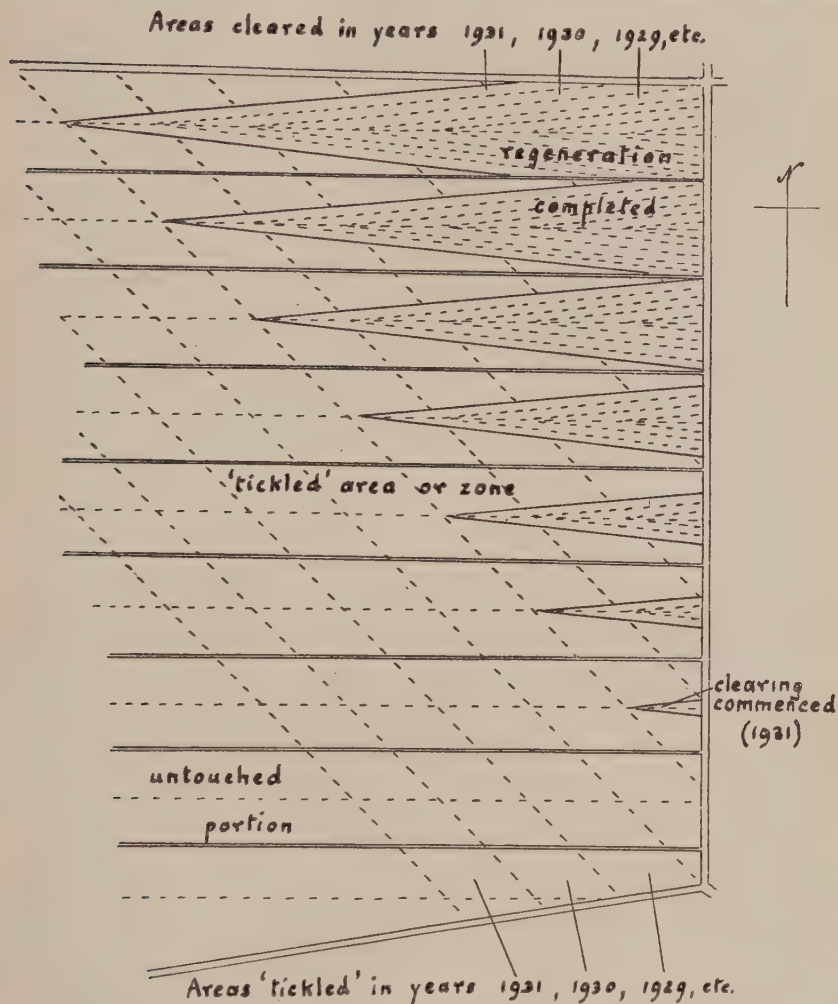
There are two forms of cuttings: firstly the enlarging of the zone, say by an average of 30–40 metres per annum, and secondly the prolonging of the wedges. Each year the wedge is prolonged by cutting along the two faces to a depth of 6–10 metres. The 'seam' set free every year is inspected and any cleaning and repair planting carried out. Work is uninterrupted, the fellings being repeated every year, and sometimes twice a year, for it is undesirable that the pines should seed up the area again and again. The diagram illustrates the method of working.

It will thus be perceived that by this method a shelter-wood system is employed, and over a larger area than a strip. The name 'Shelter-wood Wedge System' is misleading as it rather implies successive regeneration fellings in wedge form; a better title would be 'Shelter-wood and Wedge'.

In some instances the shape of the wedge is altered. In the southern Black Forest there are forests of pure spruce on fairly level ground at an elevation of 2,500 feet, which grow on a damp cold soil. When regeneration is carried out in these forests, the centre line of the wedge is moved slightly southwards. This allows more sunshine into the cleared area, which is beneficial on such a soil. Again, on the dry sandy-loam of the Rhine Valley plain the centre line may be moved slightly to the north to give a greater degree of shade to the young growth. As a rule the wedges are given a fairly acute and tapering form, so that a large surface is exposed, from which a large or small volume of timber may be cut as required, giving great elasticity in management.

In the forests of the Rhine Valley plain, which consist largely of pine and other light-demanding trees, the lower story has to be regenerated first as it contains the shade-bearing species. As early as 20 years before regeneration, the thinnings are made so as to allow one or two of the trees in the lower story to develop their crowns for seeding purposes. When regeneration of the shade-bearers has been established for 3–4 years, wedges are opened and regeneration of the pine takes place. There are also in Baden large areas of pure beech high forest, particularly on the lower hills, which are to be replaced by conifers owing to the absence of a market for beech other than for firewood. These forests are converted under the Wedge System as follows: the division of the area is as before, but the extraction lines are cut 60 metres apart; strips of silver fir, 15–20 metres broad, are planted along the centre lines of the wedges; the planting takes place 10–20 years before the systematic regeneration begins, when 'tickling' in zones is again carried out. There is no waiting for a mast year of beech, for a dense, costly thicket is not wanted. When the young beech are 4 years old, the clearing of wedges is commenced, and quick-growing species, such as pine and Douglas fir, are interplanted with the beech. The presence of the young beeches saves a lot of the planting cost, and they may form part of the lower story later on.

A point which should be mentioned is in connexion with the felling and extraction of the old timber. The trees are felled outward from the wedge, and are hauled straight out to the extraction lines which run between the wedges, so that no rotating of the logs, with consequent damage to the young



The regeneration of a compartment proceeding under the Wedge System.

growth, is necessary. It follows that on a slope the wedges must point downhill, and where, as a consequence of this, the apex of the wedge points east or north-east, a 'funnel', consisting of a cleared strip about 20 metres wide, is cut at the apex; this, it is claimed, lessens risk of windfall by 'letting the wind through'.

There is no doubt that in Baden this system has been proved very efficient in preventing wind damage, and also that there are many excellent young mixed stands already resulting from it. Wherever possible it is being applied

in that State, and very high claims are made for the system. The opinion is held by foresters there that, as the wedge-shaped cutting is simply the safest way of removing the old timber, it follows that the system may be used in its main features wherever natural regeneration is sought. In Baden they hold that the modern forest is a mixed one, and it is in order to secure an even regeneration of shade-bearing and light-demanding species that the system has been developed to its present form. The man behind the development is Dr. Philipp, late Chief of the Baden Forest Service, to whom the writer is indebted for the material of this article.

PREVENTION AND CONTROL OF DAMAGE BY WOOD-BORING INSECTS

BY R. C. FISHER

(Entomologist, Forest Products Research Laboratory)

THE insects which are most destructive to timber are the white ants, or termites, which, fortunately, do not occur in this country but are confined to warmer climates. In this country, damage by insects to structural and manufactured timber is caused chiefly by the larvae of certain beetles, and is of three distinct types, depending upon the species concerned. In the first place, there is the type of defect caused by the longhorn beetles and pin-hole borers, essentially forest insects, attacking the tree before felling, or after the felled log has lain upon the ground, and before extraction has taken place. The extent of the damage caused by these insects is often apparent only when the log is cut up for conversion. Rarely will they continue to work and increase the damage after the timber has become dried. Secondly, there are in hardwoods the defects caused by the powder-post beetles, which infest partly and recently seasoned timbers. Finally, there is the type of injury for which the death-watch beetle and its allies the furniture beetles are responsible, in long-matured and old timber.

Methods of prevention and control of the damage caused by each of these groups of insects should depend upon a knowledge of the life-history and habits of the different species, including an understanding of the conditions in wood which are necessary for the development of each group. The method in general use is to utilize chemicals in the form of wood preservatives and insecticides which will destroy the insects. A second method to which little attention has yet been paid is to attempt so to alter the conditions (physical, chemical, or biological) necessary for the development of insects in wood as to render it unsuitable for their existence. Such a method would seem to be fundamentally sounder, and for certain wood-boring insects, for example, the death-watch beetle, may yet prove to be in the long run the most reliable, or even the most practical method possible. Within the limits of this short paper it is impossible to enter into greater detail than merely to mention briefly existing methods of prevention and control, to indicate the lines upon which research is being developed, and to show how new methods must depend more and more upon an accurate knowledge of the biological and ecological factors of importance in the life of the insects.

PIN-HOLE BORERS AND LONGHORN BEETLES

Pin-hole borers and longhorn beetles being forest insects do not come strictly within the scope of this paper, but they are mentioned because timber importers and users are well acquainted with the injury they have caused

before the timber reaches their premises. Prevention of this type of damage is often a silvicultural problem, and calls for the co-operation of forester and entomologist. In many instances injury results from unsuitable silvicultural conditions under which trees have been growing, as, for example, in the case of the damage caused by the larch longhorn beetle, *Tetropium gabrieli* Weise, when the presence of the insect acts as a useful indicator that the trees have been attacked by fungus or are otherwise in an unhealthy condition. In the case of the pin-hole borers, much can be done to reduce the injury they cause to timber after felling by rapid extraction and conversion, by kiln-drying, by the barking of logs, by immersion in water, or, with certain types of timber, by sun-baking, a method which has been investigated by Craighead (5) in the United States of America, but which is not always possible. Experiments have been carried out in the United States and Europe with spray solutions applied to logs to reduce the losses caused by these groups of insects; although many sprays have been tried, none have proved useful in practice: most of the sprays found of use are effective only for a limited period (6). Recently Craighead and St. George (7) have studied the possibility of injecting wood preservatives into the sapwood before the tree is felled, thus making use of the forces within the living tree.

POWDER-POST BEETLES

In this country the powder-post beetles present a more difficult and more urgent problem; the extent of their ravages is dealt with in detail in *Forest Products Research Bulletin*, No. 2 (12). Since the publication of this Bulletin, however, the Forest Products Research Laboratory has carried out a survey of the conditions with regard to insect damage to timber throughout England and Scotland. Special attention has been given to the occurrence and distribution of the *Lyctus* powder-post beetles, and it has been shown that these insects are widespread wherever stocks of seasoned oak, ash, walnut, or other susceptible hardwoods are held. The losses caused by the *Lyctus* beetles continue to be serious, and the prevention of their increase is one of the most important and difficult timber-insect problems with which we are faced. The first essential in this work is a realization of their responsibilities by all branches of the timber and allied trades which use susceptible timbers. It is possible to do much to restrict the spread of the insect by the immediate segregation of infested material, its subsequent sterilization by moist-heat treatment, if kiln facilities are available, or failing that, the destruction of obviously badly infested boards. Ability to recognize the insect and its damage, and attention to yard hygiene (the immediate destruction of discarded sapwood or other waste materials) are two simple control methods which, if adopted on a large scale, would be invaluable for reducing the losses caused. Moist-heat sterilization is a valuable remedy, but while a suitable treatment can now be prescribed, further work is required, and is in progress, to ascertain the minimum conditions of time, temperature, and humidity to which infested timber must be exposed in a kiln for the destruction of all stages of this insect. The use of insecticides and wood

preservatives is restricted to the treatment of small articles of furniture or panelling, and even then is often of doubtful value. In timber yards or in factories the use of an insecticide is neither practical nor economic. There is, however, the need for an efficient and cheap wood preservative with which timber could be treated after sterilization treatment, in order to prevent subsequent infestation by the beetles which deposit their eggs within the pores or vessels of the wood. A substance which will effectively close the pores, thereby inhibiting oviposition, is required, but the treatment must not discolour the wood, nor harm it in any way for varnishing, polishing, or finishing as may be required. The problem is a difficult one and has not yet been solved.

FURNITURE BEETLES

The control of the death-watch beetle and its allies the furniture beetles also presents a most difficult problem. Much attention has recently been drawn to the death-watch beetle (*Xestobium rufo-villosum*) as a result of the large number of valuable and historic buildings in which the insect has caused serious damage to the roofing timbers. The death-watch beetle and its allies may be regarded from two points of view: on the one hand, as destructive pests to be destroyed by whatever means may promise success; and on the other, as a group of insects, showing various adaptations to life in a somewhat special environment which are well worthy of investigation. The first point of view is, apparently, the more practical one, but it may be that the second will, in the long run, lead to more effective control of the beetle's ravages than has hitherto been obtained.

The first systematic investigation of the death-watch beetle (*Xestobium*) problem was begun in the Imperial College of Science and Technology by the late Professor Lefroy in 1914. At that time, and indeed until some 5 years ago, the investigation was wholly governed by the desire to devise some remedy against the beetle's ravages. Insecticide formulae were drawn up, literally by the dozen, despite the fact that knowledge of the details of the beetle's life-history and habits was lacking. The result of this work was that various first-aid measures against the death-watch beetle were made available, and these are now extensively used by architects and builders. Accordingly, the control of the beetle's ravages—in so far as it can be attained on the basis of our present knowledge of its economy and habits—may safely be left in their hands, while the entomologist acquires more knowledge of the beetle and the biological problems which it presents.

Contributions to our knowledge of the beetle's life-history have been made by Dr. Gahan (13) and others, but the contributions towards an understanding of its ecology have come indirectly as the result of the advance in our knowledge of the biology and physiology of insects in general. It has been found, for example, that in certain insects unfavourable conditions of temperature and moisture produce sterility in two or three generations, and it may be that similar unfavourable conditions affect the death-watch beetle in the same way. For instance, it is a peculiar feature of death-watch beetle infestation that

attack often ceases before all the available wood has been destroyed. Some factor or factors are operating to bring about this, but what these are is at present not known. Sterility of the beetles resulting from certain unsuitable conditions may possibly be the cause. Adequate ventilation of buildings may act in this way, and it may be mentioned in passing that the control of the death-watch and furniture beetles is sometimes due as much to improved ventilation in buildings as to the application of insecticides. It is also interesting to record that as a source of living *Xestobium* beetles, required for our investigations at Princes Risborough, partly decaying willow-trees in the neighbourhood of the Laboratory have proved much richer than timber from buildings in which the beetle and its grubs were believed to be active and numerous. Old willows and oaks are the natural habitat of *Xestobium*, and it may be assumed that when timber is badly attacked the conditions prevailing in it must correspond more or less closely to those of the insect's natural habitat.

A careful study of the biology and physiology of the death-watch beetle and its allies is therefore not merely of scientific interest but is of high practical importance, and while there will always be differences of opinion among architects and builders concerning the value of this, or that, method of control, a fuller knowledge of the beetle as a living organism will afford a sound basis for the application of control measures and enable us more readily to decide when such measures are really urgent and to what extent they are really successful. The acquisition of that fuller knowledge is the most useful contribution which can be made to the solution of the 'death-watch' problem, but it entails the conduct of prolonged experimental work on an insect which is most difficult to rear and handle.

INSECTICIDES AND PRESERVATIVES

Pending the acquisition of such information, the use of insecticides and preservatives provides a means of attempting to restrict the activities of this insect. In view of their wide application and in view of the difficulty of judging the value of treatment, it may be well to consider briefly the problem presented by their use.

It has already been indicated that the application of such substances for the control of wood-boring insects is much restricted because of the many conditions which they must fulfil, in addition to possessing a marked toxic power. These conditions have been fully outlined by the late Professor Lefroy (15), and among them may be mentioned the following: non-inflammability, non-poisonous to man, lacking smell, not causing discoloration of timber, non-volatile, of good penetrative power, &c. While insecticides have their place under certain conditions for use on attacked timbers, the work that so far has been carried out upon them has, of necessity, been purely of an empirical nature, and their use must be regarded as of temporary value until more is known of the life-history of the insects. This applies particularly to the death-watch beetle. At Princes Risborough we have been requested to carry out tests with new preparations, but have been unable to undertake this work

because it is first of all necessary to have large stocks of the insects concerned in all stages so that it would be possible to infest at will standard test samples of timber to be treated with the preparation under examination. Our knowledge of the life-cycle of the death-watch beetle does not yet allow of rearing the species—nor indeed of the common furniture beetle, *Anobium punctatum*—in the numbers required, so that at present it is not possible to use these insects in a satisfactory and reliable insecticide test. It is interesting to note that recent work in India (9, 17) and in Australia (8) on a study of wood preservation in relation to attack by white ants, has shown that even after many years' work it has been found essential to devote greater attention to studies of the distribution and biology of the termites themselves. Just as in this country we are at present attempting to rear large numbers of furniture beetles, efforts are being made by Hill (4) in Australia to rear in the Laboratory colonies of termites to enable tests on treated and untreated wood to yield results quickly, and to supplement tests carried out under field conditions. A similar situation exists in India, where at Dehra Dun an entirely new programme of work has recently been drawn up for investigating the problems of wood preservation in relation to termite attack. These problems, particularly with reference to methods of determining the natural durability of timbers or the value of different preservatives, have been discussed by Popham (17) and Dover (9). The fundamental principle throughout is an accurate knowledge of the life-history and habits of the insects which it is wished to control.

At the present time at Princes Risborough it is possible to use only *Lyctus* beetles and oak sapwood in the insect portion of the Laboratory's programme of work upon the determination of the relative toxicity of wood preservatives. These insects are used because they are the only species which can be reared in sufficient numbers and with which control samples can be infested easily. The results of this work are of value, not only for indicating the relative toxicity of the preservatives tested, but also for determining their suitability for preventing egg-laying whilst at the same time not interfering with the working qualities of the wood. The results from these tests must however not be taken to determine the value of a substance for the prevention of attack by other wood borers which infest heart as well as sapwood.

There is scope for a study of the use of fumigants for the control of wood borers, particularly when the application of sprays is impracticable because of the presence of paint-work which must not be damaged by the treatment. Within recent years HCN has been used—it is claimed—successfully for the fumigation of insect-infested timbers in buildings in Germany (15). The value of such a treatment for death-watch beetles on a large scale in this country has not yet been determined, nor is it yet known whether such a method would be a practical possibility. Much work of an experimental nature with this and other fumigants is still required.

The development of new-wood preservatives or the testing of such substances are at present regarded as a very secondary part of the programme of work of the Entomology Section at Princes Risborough. The primary object of

our insect work is to determine the conditions which are necessary for the development of the different groups of insects injurious to timber, because it is believed that a thorough and detailed knowledge of the life-history of the insects must form the basis of all sound methods of control and prevention of damage. For instance, it is desirable to ascertain why these groups of insects each confine their attack to timber at a different stage in its utilization. In this connexion, it is believed that the cessation of the activity of the pin-hole borers in dried timber is due to the absence of the moisture (present in green timber) necessary for the fungi which grow on the walls of their tunnels and upon which they feed. Even in this group of insects, however, our knowledge of the food habits and the food materials in relation to moisture and other conditions in the timber is scanty. Again, in the case of *Lyctus*, experimental work at Princes Risborough has shown that these beetles and their grubs, and the death-watch beetles and their grubs, differ in their food requirements (2). Their occurrence and development is apparently governed by physical and chemical factors not yet fully understood.

In conclusion, and whilst referring to the need for information upon the physiology of nutrition of wood-boring insects as of fundamental importance in the development of sound and satisfactory methods of preservation, I would refer very briefly to the problems involved, which have been so admirably summarized by Uvarov (19). Since this summary was written, some progress has been made and at least one new conception brought forward of the mode of nutrition of wood-boring insects. It has always been a matter of wonder how these insects could derive their nourishment from such an apparently non-nutritive material as wood. It has been known for some time that pin-hole borers depend upon the presence of certain fungi (ambrosia) in the wood, and that they feed upon these organisms growing on the walls of their tunnels. It is believed that other borers (e.g. Siricidae) depend upon a fungus to pre-digest the wood before it is suitable for the insect—a problem at present being investigated by Cartwright (3). In other instances there is a school of thought, represented by Buchner (1) and his colleagues, which believes that wood is made available as a food material for insects as a result of the activity of internal symbionts, acting in a manner similar to the cellulose-digesting protozoa which Cleveland (4) has shown to occur in the alimentary canal of the termites, and without which, generally speaking, these insects cannot exist for a prolonged period upon cellulose or woody materials as food. Buchner's conclusions have been reached after careful anatomical examination of numbers of different wood-boring insects and their larvae. Recently, however, Ripper (18), using biochemical methods, has thrown considerable doubt on the assumed role of symbiotic micro-organisms in wood-eating insects. He claims to show that cellulose is made available to the insects as a result of the activity of a cellulase or cellulose-digesting ferment in the digestive juices of several wood-boring insects. The subject is of the greatest interest and importance in the development of new methods of wood preservation. Further research on biochemical and physiological lines is, however, necessary to clear up this controversial

subject. Uvarov (19) draws attention to another aspect of this subject in relation to wood preservation when he points out that 'the resistance of certain plants to wood-feeding insects with the help of internal symbionts, if such are present, may be due to the unsuitability of the plant for the organisms symbiotic with the insects. In other words, from the point of view of control, in such cases the best line of attack would be, not against the insects, but against their symbionts.' The suggestion is, as he takes care to state, purely theoretical, but it is one worth studying most carefully, since the practical results may be very great. In this work the first essential is to determine the source of nutrition of different insects boring in wood at the various stages of its age and history, and then to ascertain how this is made available to them.

The problems of wood preservation for the prevention and control of damage by insects therefore cover a vast field, and their solution cannot hope to be found by the mere application of various mixtures of chemicals to attempt to destroy insects, the very feeding habits of which are not fully understood. In attempting to elucidate the subject, much assistance can be rendered by the wood chemist on the lines of work which Mr. Campbell of the Chemistry Section of the Laboratory has already carried out on behalf of the Entomology Section, when he investigated the difference in the feeding of *Lyctus* and *Xestobium*. Similar studies have since been carried out by Falck (10, 11) in Germany, where he investigated by comparative analysis of sound coniferous wood and frass the nature of the feeding of the common furniture beetle, *Anobium striatum*, Ol., and the dry wood longhorn borer, *Hylotrupes bajulus*, L.

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METHODS OF APPLYING ANTISEPTICS

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INTRODUCTION

THE effect of antiseptics on the control of wood-destroying fungi has been dealt with in a previous paper,¹ and a large number of experiments and records demonstrate that wood fully impregnated with an efficient antiseptic will remain immune from attack so long as the preservative remains in the wood in a sufficient quantity and unaltered in composition. It is not proposed to deal here in detail with the various antiseptics suitable for the preservation of wood, except to state that there is no shortage of either quantity or variety of chemicals which are toxic to wood-destroying fungi, and which would consequently inhibit the growth of such fungi for such a time as they remained in the wood in the necessary quantity. The most obvious and probably most widely used method of applying antiseptics is by surface application, usually by means of a brush. Such surface application results in what might be called skin-deep penetration which seldom exceeds $\frac{1}{16}$ inch and is usually considerably less. This thin band of impregnated wood being toxic to the wood-destroying fungi serves as a protection to the untreated wood in the interior of the piece. If this protective band remained intact and the timber was free from infection before treatment, there is no doubt that it would last indefinitely. However, in actual practice two factors operate which prevent these conditions being maintained.

Firstly. The coating can seldom be kept intact, owing to mechanical abrasion or to splitting caused by shrinkage stresses. Once the untreated surface is exposed the conditions for preservation no longer hold good, and a loophole is made for fungus attack which may spread rapidly through the unimpregnated interior.

Secondly. The usual types of antiseptic are not sufficiently permanent and may disappear in time either by evaporation or by being washed out by water. Consequently when the antiseptic has disappeared, partially or completely, the conditions again do not hold good, and the wood is subject to attack.

Actually in practice either or both of these factors operate, so that a single brush treatment of antiseptic, whilst preserving the wood for a certain time, is not a really efficient method of preservation.

It will be seen that the most obvious method of overcoming these objections is to obtain a much deeper impregnation of the antiseptic. If a sufficiently deep impregnation is obtained, firstly, the usual mechanical abrasion or splitting will not be sufficiently deep to expose the untreated timber, and secondly, the

¹ 'The Toxicity of Preservatives against Wood-destroying Fungi', R. St. G. Cartwright, *Forestry*, v, No. 2, pp. 138-47.

timber absorbs a much larger volume of preservative with only the same surface area exposed to loss by evaporation or washing, and consequently the proportionate rate of loss of preservative is much slower. Practical results have indicated that complete impregnation of a piece of wood of fair sized section is not necessary, a depth varying from $\frac{1}{2}$ to $1\frac{1}{2}$ inches having been found usually effective. The work of those interested in the preservation of wood by antiseptic means has thus been focussed on obtaining this required depth of penetration as uniform as possible throughout the piece by the most economical methods.

SURFACE TREATMENTS

In the case of brush or surface treatment, better penetration is obtained by applying the preservatives hot, if of creosote type, and provided the process is repeated periodically, say every 2 or 3 years, the timber can be made to last quite a long time. Various chemicals have been suggested at one time or another for adding to an antiseptic with a view to reducing their surface tension, and so giving them greater wetting properties and greater penetrating powers. Whilst in some cases slightly greater absorptions are obtained by the addition of these wetting agents, the increase is hardly sufficient to justify their use.

Spraying is probably slightly more effective than brush application, as the surface of the timber is more thoroughly covered, whilst dipping is more effective still. By prolonging the duration of dipping or steeping the timber, the absorption is further increased, but at a very slow rate. In the case of steeping, different results are obtained by antiseptics of the oil type and those of the aqueous solution type. In the former case penetration is due to capillarity and mass movement of the oil, whilst in the latter case penetration is due both to capillarity and also to diffusion of the salt from the solution through the wood. This latter movement occurs only when the timber is in a green or wet condition. Thus with green or partially dried timber, better results are obtained by the steeping process when using aqueous solutions than when using oils. This method was adopted in the Kyanizing process which consists of steeping the timber in an aqueous solution of mercuric chloride. The corrosive nature of this salt prohibits its use in contact with iron, and so the pressure processes are not applicable. It will be realized that the usual method of measuring the absorption, that is, by measuring the increase of weight of the timber during treatment, is not applicable in the steeping process with aqueous solutions, due to the selective absorption of the solute. In this case the absorption of dry salt can only be measured by tedious analysis.

PRESSURE TREATMENTS

The introduction of the pressure process for the impregnation of timber about 100 years ago has been the most effective step towards the obtaining of better penetration of the antiseptic. By the use of pressure, absorptions and depths of penetration can be obtained far exceeding those obtained by brushing, dipping, or steeping, and exceptional durability has resulted with pressure-treated timber. The Bethel process as introduced in 1838 is in general use

to-day, and when properly applied gives very satisfactory results. This process consists essentially of impregnating the timber in closed cylinders with an antiseptic under pressure. Several processes have since been introduced, all depending on pressure difference for forcing the antiseptic into the wood. The most noteworthy is probably the Rueping process where the timber is subject to an initial air pressure previous to impregnation of the antiseptic at a higher pressure. The impregnation is caused by the difference between these two pressures, the advantage of the process being that the compressed air inside the timber expands when the pressure is reduced to atmospheric, expelling a considerable quantity of the injected antiseptic. Thus a deep impregnation may be obtained with a smaller net absorption of creosote. This process has advantages only when the following conditions hold:

- (1) That the timber to be impregnated will readily absorb large quantities of the preservative.
- (2) That the preservative in use is highly toxic.
- (3) That the timber so treated is not for use under conditions where the rate of loss of the antiseptic is likely to be high.

Thus, for example, the Rueping process is eminently suitable for telegraph poles of Scots pine or Baltic fir in the round, but is not suitable for marine timber subject to the constant action of water. The Lowry process is a modification of the Rueping process, the initial air pressure being atmospheric, whilst the timber after impregnation is subject to a pressure less than atmospheric.

In a pressure process the cycle of pressure differences both below and above atmospheric can be and usually are varied considerably to obtain desired results. When treating by the Bethel process it is usual in practice to first apply a vacuum to the timber. This vacuum serves two purposes. Firstly, it increases the pressure difference to which the timber is subjected (and consequently increases the pressure causing impregnation), and secondly, an initial vacuum considerably facilitates the filling of the treating cylinder with the antiseptic which is generally kept in a tank at a lower level. It is sometimes stated that the initial vacuum by drawing the sap or moisture from the cell spaces facilitates the subsequent entry of the antiseptic into the wood. With the lengths of vacuum period in general use, this drying effect is negligible even on fairly green timber, and the advantage due to this supposition is doubtful. Intermittent steaming and vacuum treatment over a considerable period will remove a certain amount of moisture from green timber, but the drawbacks attendant on the use of timber impregnated whilst green outbalance the advantages gained by this method of seasoning. In the case of the Boulton or boiling under vacuum process the initial vacuum is applied to the timber whilst submerged in heated creosote. By this means the boiling-point of the water inside the wood is reduced, enabling it to evaporate at a temperature below the normal. By this method considerable drying of the timber can be effected, but this is purely a heat effect, the vacuum enabling a lower temperature to be used with consequently less damage to the wood.

The pressure period is by far the most important factor affecting the amount and depth of impregnation, and in usual practice the required absorption of antiseptic is obtained by controlling the magnitude and duration of the pressure. Generally speaking, the rate of impregnation during the pressure period is fairly uniform for a time, and then gradually slows down until no further impregnation is obtained. When this point is reached the timber is said to have been treated 'to refusal'. The rate of absorption varies considerably with different species. Whilst species like beech and Scots pine sapwood will be completely impregnated under pressure within an hour or two, others like Douglas fir, larch, and oak heartwood would not be completely impregnated even under pressure for several days. Various methods have been suggested for increasing the rate of penetration. It is usually recognized that better impregnation is obtained by applying the pressure gradually, although I have no results to definitely show this. Alternating pressures have been tried at various times, that is, the pressure has been applied and then reduced to zero, the operation being repeated continually. Pressure cycles of this type, both at fast rates of 500 per hour and slow rates of 4 per hour, do not appear to result in improved impregnation. Generally speaking, the higher the pressure the better the impregnation, but in practice it is not advisable to exceed 200 lb. per square inch, as above this pressure the timber is likely to suffer mechanical damage. The pressures used in commercial creosoting range from 80 to 180 lb. per square inch.

The principal object of the final vacuum is to clean up the surface of the timber when using creosote so that it is not wet and dripping when removed from the cylinder. It is used in the Lowry process to extract a surplus of creosote from the timber, but the amount of creosote that can be extracted by a final vacuum is comparatively small compared with that expelled at the end of the Rueping process.

OPEN-TANK PROCESS

The principle involving the use of a pressure difference to force an antiseptic into wood may be applied without employing a closed impregnating vessel or pressure pumps in what is known as the 'open-tank hot and cold process'. Timber in an air-dry condition contains approximately 50 per cent. volume of minute air spaces. If this timber is heated in a liquid contained in an open vessel the contained air expands considerably more than the wood and a certain amount escapes through the liquid in the form of bubbles. On cooling, the remaining air contracts, and the liquid is sucked into the timber. It will thus be seen that impregnation is caused by pressure difference due to varying temperatures. The pressure is comparatively small, being of necessity always considerably less than one atmosphere, but its time of application may extend over a number of hours. With certain timbers excellent results can be obtained with the open-tank process considerably better than those obtained by prolonged steeping at constant temperature. Its application is more for estate purposes and similar work where small quantities of timber are required to be

treated without a large capital outlay in plant. For large quantities of timber and for the more refractory species, the usual pressure processes are better and more economical.

Usual methods of pressure impregnation involve equal pressure of the liquid on all faces of the timber. It is a well-known fact that impregnation is more easily effected in a direction parallel to than across the grain. This principle has been adopted in the Boucherie process which has been used for a long time in France for the treatment of telegraph poles. The preservative (in this case copper sulphate solution) is applied at the end of a log by means of a special cap to which is attached a pipe leading to an elevated tank of the solution, so that a hydrostatic head of several feet is obtained to force the liquid along the log. The latter is usually treated in a green condition so that the preservative entering at one end forces the sap out at the other. The process may occupy several days until the preservative appears at the other end. Attempts have been made to accelerate this process by applying the preservative at a relatively high pressure over one end of the log and subjecting the periphery and other end of the log to a vacuum. The practical difficulties of this process are considerable, as the injected liquid will not always travel through the length of the log, but will be short circuited by splits and defects in the log. Further, with logs containing distinct heart and sapwood, the sapwood being generally more penetrable than the heartwood, the treating liquid follows the path of least resistance and impregnation is confined to the more easily impregnated sapwood. However, green logs of species such as beech and sycamore with no distinct heart and sapwood can be more or less completely impregnated in a few hours with aqueous solutions of various salts, but the actual absorption of the liquid is small compared with that obtained by the usual pressure impregnation of seasoned material. The process only appears to be applicable with aqueous solutions and not with creosote oils.

INCISING

With certain refractory timbers, considerable difficulty has been experienced in injecting sufficient preservative into the timber by pressure application in order to ensure satisfactory protection. Higher and prolonged pressures, while tending to increase the absorption, do not overcome the difficulty satisfactorily as the extra absorption is usually local and the protection of the timber is not uniform. Various attempts have been made to overcome this difficulty, but perhaps the most successful so far is the operation known as incising. Incising was first introduced in Canada for the treatment of Douglas-fir railway sleepers. It consists of making a number of small incisions about $1\frac{1}{2}$ inches long and $\frac{3}{4}$ inch deep over all the lateral faces of the timber before treatment in order to aid subsequent penetration of the creosote under pressure. The incisions are made parallel to the fibres, so that the latter are cut across as little as possible and merely parted. The spacing of the incisions is usually about 1 inch laterally and about $2\frac{1}{2}$ inches longitudinally, but the rows are staggered $\frac{1}{3}$ inch so that the rows are $\frac{1}{3}$ inch apart laterally. The spacings of the incisions

is determined by the lateral and longitudinal penetration of the creosote, and is arranged so as to obtain a uniform band of impregnated wood to the depth of the incision. For instance, on the above spacing the creosote would be required to penetrate $\frac{1}{8}$ inch laterally on each side of the incision and $3\frac{3}{4}$ inches longitudinally in order to give the impregnation desired. The depth of penetration into the sleeper being equal to the depth of the incisions. Results have shown that with Douglas-fir railway sleepers increased absorptions are always obtained by incising, varying from 30 to 60 per cent. However, what is more important still is that the distribution of the creosote is much more uniform, and equal protection is obtained all round the sleeper. It is considered that incising could be economically applied to other species besides Douglas fir. Consider, for instance, railway sleepers of Baltic fir or Scots pine. This class of sleeper will readily absorb considerable quantities of creosote and in service give a life of 20 to 25 years. The creosoting, however, is not carried to refusal, and inspection of such sleepers after creosoting demonstrates that considerable quantities of creosote are held in the sapwood, whilst the penetration on the heartwood face is comparatively small. Consequently, at the end of the 20 to 25 years' service, these sleepers are rejected principally because of decay of the heartwood commencing at the least protected faces, whilst a considerable quantity of creosote remains in the still sound sapwood. If such sleepers were incised on the heartwood faces before creosoting, and then treated by a Lowry or modified Rueping process so that treatment was carried on nearer to the refusal point, a much more uniform impregnation would result with the same or even less net absorption of creosote. It is suggested that sleepers treated in this manner would give a longer life than at present, and a life more approaching the mechanical life of the sleeper. Although primarily introduced for the treatment of Douglas-fir sleepers, incising is being gradually adopted for other refractory timbers. In Canada the butt ends of Western red-cedar poles are incised before treatment by the open-tank process in order to give better protection of that part of the pole which is most subject to decay. Experiments at the Forest Products Research Laboratory at Princes Risborough have shown that with larch poles an increase in absorption of creosote of 30 per cent. is obtained by incising, besides giving a more uniform penetration.

A process similar to incising has been introduced in Germany which consists of making a number of small shallow saw-cuts on the surface of the timber across the grain and not along the grain as is usual with incising. These cuts are made with circular saws about 4 inches in diameter which are depressed into the surface of the timber, making segmental grooves. The saws are spaced so that adjacent grooves are not in direct line but are staggered. With such a large area of end-grain being exposed impregnation is considerably accelerated. However, the fibres are cut completely across on the outside surfaces where compressive and tensile stresses due to bending are at a maximum, so that this operation would appear to considerably weaken the timber mechanically. Since, however, mechanical strength is usually secondary to durability in the case of railway sleepers and marine timbers, the increased protection against decay would

outbalance the loss in strength, and the process would therefore appear to offer distinct advantages.

DIFFUSION PROCESS FOR TREATMENT *IN SITU*

Most methods of impregnating timber with antiseptics are carried out prior to the timber being placed in position. It is sometimes desirable, however, to impregnate the timber after it has been in position possibly for some years.

A process for the impregnation of fence-posts and telegraph poles *in situ* originated in Germany several years ago. This is known as the Cobra process, and consists of injecting into the post at numerous points by means of a special implement an antiseptic in paste form. The antiseptic then diffuses from the incisions round the pole, giving a completely impregnated band of wood equivalent to the depth of the incisions. Tests have shown that where the pole was sufficiently wet, that is, at and below ground-level, the diffusion was such that complete impregnation of the outer band occurred in about 12 months; where the pole was dry, no diffusion occurred. A later development of this method consists of wrapping a bandage containing the antiseptic paste round the pole at ground-level. Diffusion then occurs from the concentrated paste towards the interior of the pole. A further method suggested by the Forest Products Laboratories of Canada consists in placing over the butt end of the pole a metal container holding the antiseptic salt which gradually diffuses up the pole after erection. The latter method would appear to be effective as diffusion is most rapid in a longitudinal direction, but it is, of course, not easily applicable to poles *in situ*. All these methods depend on the diffusion of water-soluble salts to obtain the required impregnation, and are therefore not applicable with preservatives of the oil type, nor to timbers other than in a wet condition.

These limitations prevent the use of diffusion processes for the impregnation of oak roofing timbers attacked by death-watch beetle. Surface application of an insecticide is not altogether an effective control of the damage, and as yet no method has been found of obtaining sufficient penetration of an insecticide to kill existing beetles and larvae, and prevent further attack. Such a method would considerably facilitate the protection of old timbers in historic buildings from death-watch beetle which is at present so difficult to eradicate without complete removal of infected timbers.

A CHEMICAL APPROACH TO THE STUDY OF WOOD PRESERVATION

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WITH relatively few exceptions all woods are susceptible to decay in one form or another. At the same time it is well known that provided wood can be impregnated satisfactorily with a powerful antiseptic such as coal-tar creosote, it will be proof against serious decay for the major part of its mechanical life. For obvious reasons, antiseptics which possess properties which are disagreeable to man cannot be used under all circumstances, and thus scientific research is faced with the problem of finding reasonably inexpensive means to preserve timber against certain forms of organic decay, without at the same time imparting to it any undesirable qualities.

In considering this problem the suggestion presents itself that some attempt should be made to understand the agencies which combine to make such woods as teak, greenheart, bald cypress, redwood, &c., so resistant to decay, and to explain at the same time why, as a general rule, the heartwood of some species is more durable than the sapwood. It comes as no surprise, therefore, to learn that these natural phenomena have long been the subject of much speculation and some research. Again, it is frequently suggested that timber felled in autumn and winter is more durable than timber felled in spring and summer, but opinions on this question are still at variance. For instance, Hawley (14) and Koehler (22) among others have stated that intrinsically wood is equally susceptible to decay at all times, but that under natural conditions the risk of infection is greatest in spring and summer when the agents of decay are most prolific. On the other hand, Gauman (13) has sought to prove by an exhaustive series of laboratory and field experiments that timber felled in spring and summer is definitely more susceptible to decay by reason of certain favourable physico-chemical conditions which obtain in wood during these seasons. This important work awaits confirmation, and the results require further explanation, since the suggestion concerning variations in the colloidal condition of wood with varying climatic conditions constitutes an entirely new conception which can only be accepted in the light of a considerable body of experimental evidence.

Reverting now to the question of natural durability, the consensus of informed opinion appears to be that durability is conferred on woods in varying degree according to the toxicity and distribution of certain extraneous components or extractives such as oils, resins, tannins, &c. Woods which are rich in toxic extractives are more durable than woods of which the extractives are non-toxic. These findings have been amply demonstrated in the work of Hawley, Fleck, and Richards (15) who determined the relative toxicity towards

Fomes annosus of the aqueous extracts of a number of American woods, and similar conclusions concerning the toxicity of wood extracts have more recently been arrived at by Sowder (30). Thus it follows that the early belief that the non-durability of sapwood is due to the presence in the sap of starches and sugars which are readily assimilable by decaying organisms must be abandoned in favour of the view that in any species where the heartwood is observed to be more durable than the sapwood the principal cause of this disparity is to be sought in the presence in the heartwood of toxic extractives.

The natural deduction from the above considerations has been that it should be possible to preserve non-durable woods by impregnating them with toxic extracts from durable woods. From time to time experiments have been conducted to this end. For instance, Hawley and Wise (17) draw attention to the discovery by Oshima in 1919, that the volatile oil of Cypress pine is toxic to termites, and when this oil is injected into Japanese pine (a non-resistant wood) the attack of termites is prevented. In this connexion, Dadswell (8) reports in a recent paper that experiments are at present in progress in Australia with the object of determining the true nature of the toxic principle of three species of Cypress pine (*Callitrus* spp.). This author states, however, that the results of such investigations must be accepted with caution, since the toxic principle, when discovered, may not be toxic at all varieties of termites. In other words, one is at once confronted with the fact that apart from the difficulties of securing proper redistribution of the toxic principle in a non-durable wood the toxic principle itself may exhibit a specificity for one kind of decaying organism only.

In the realm of fungal decay Schorger (27) refers to the statement by Wehmer that *Merulius lacrymans* attacks coniferous woods but not oak, because the tannic acid in oak is toxic to this fungus. At the same time it is known that *Merulius* grows vigorously in the presence of acids other than tannic acid, and that oak is attacked by other fungi which must therefore be unaffected by tannic acid in certain concentrations. It therefore follows that while extended chemical investigations of the natural agencies which promote durability may help to point the way to more efficient means of preserving the less durable woods of everyday use, it should be borne in mind that the toxic extracts of individual woods may be merely specific in their action, and that insects and fungi on their own part also display marked specificity. The immense variety of wood extractives which may have toxic properties, and indeed the immense variety of commercial preservatives of reputed toxic properties, coupled with the fact that so many woods are susceptible to attack by specific organisms, suggest that so long as the criteria of preservation are assessed in terms of the toxicity of certain substances towards laboratory cultures of a few wood-rotting organisms, the search for ideal methods of preserving wood may be unnecessarily long. It is therefore suggested that present methods of investigation can be greatly enhanced if concurrent attention is directed to the more intimate study of the relationships which exist between decaying organism and host. There can be no doubt that the work of Curtin (6) has been a source of

encouragement to research of this type. This author has established that in the course of the decay of wood by fungi certain acids are produced. Although it has long been known that most fungi grow best in acid media, the work of Curtin on the preservative properties of zinc-meta-arsenite (7) has been instrumental in showing that these acids might be made to form a link in a novel process of preservation. Wohlman and Pflug (32) have expressed doubt as to the efficacy of the zinc-meta-arsenite process and criticized the data of Curtin, but the stimulative effect of this work remains. Preservatives which in themselves are dangerous poisons to man must be of strictly limited application, for even though the zinc-meta-arsenite process were an unqualified success it could not commend itself universally.

In laying bare one factor in the relationship existing between decaying organism and host, Curtin may be said to have initiated the search for other factors which may be of equal or greater importance from the standpoint of wood preservation, and thus various workers have been led to inquire into the detailed effects of insects and fungi on the carbohydrate-lignin complex which constitutes the major portion of all woods.

The question naturally arises as to which component or components of wood are available to these organisms as a source of food, for there can be no doubt that the ultimate action of most insects and fungi on wood is a chemical disintegration, the nature and course of which are determined by the catalytic effect of enzymes secreted by the organism or organisms concerned. It would thus appear to be feasible that if decay could be considered in terms of its ultimate chemical effect on wood substance, the future objective of preservative treatments might be the inhibition of certain definite chemical reactions instead of the poisoning of all organisms that might invade a piece of timber. There are reasons for the belief that the number of such chemical reactions must of necessity be small, and that at least one is common to all types of decay, so that while it cannot be claimed in advance that it would be simpler to inhibit these reactions than to arrive at the ideal preservative by trial and error, it can be said in favour of this chemical method of approach that it is not likely to be hampered to the same extent by the problems of specificity which have made current methods so difficult.

It is now proposed briefly to review the significant steps which have been made in the study of the chemistry of wood decay, and to refer to some experimental work which has been carried out at the Forest Products Research Laboratory during the past 4 years in order to adduce evidence in favour of the contentions which have been made above.

In the first place, it should be pointed out that elementary chemical analysis is of little service in a study of this kind, since any variations in C, H, and O caused by decay would convey little information of a conclusive character. It is equally true that the chemistry of wood is at an early stage of its development, since it is impossible to ascribe a universally acceptable formula to any of its principal components, or, for that matter, to many of its extractives. The formulation of a completely satisfactory system of wood analysis, therefore,

is for the present an impossibility, but at least one system is capable of yielding results which have been shown to be of great statistical value. This system is fully described by Schorger (28) and Hawley and Wise (20), and has formed the basis of some of the work which is about to be described. The principal components of wood are:

Cellulose	50-60 per cent.
Lignin	20-35 per cent.
Pentosans	10-20 per cent.

In addition to these constituents, Schorger's system of analysis provides for several other estimations such as water-soluble, alkali-soluble, and ether and alcohol-soluble material, but it should be emphasized that the system is merely proximate in character. That is to say, the sum of the percentages of the constituents does not give 100. This is briefly explained by the fact that it has so far been found impossible either to isolate by means of simple operations a wood cellulose that does not contain some pentosans and a trace of lignin, or to obtain lignin which does not suffer some constitutional change in the course of its isolation. There must therefore always be a certain degree of overlapping among these components, but despite this fact and the added consideration that definite chemical formulae are not available, it can be shown, in the first place, that the above system of analysis succeeds in differentiating a complex natural product into certain reasonably definite entities, and, secondly, that these entities are affected in different ways by the different organisms which cause decay.

It is a matter of history that the first analysis of wood decayed by fungi was carried out by Rose and Lisse (26) in 1917. The decaying organisms in this case were not identified, but later work by Mahood and Cable (23), Bray and Andrews (2), and by Hawley (16) and his collaborators in the United States of America, Falck and his collaborators (12, 9), and others in Europe has produced new methods of studying these phenomena, and at the same time elicited a considerable amount of experimental evidence which has formed the basis of several theories concerning the mode of attack of wood by fungi. With regard to the feeding habits of wood-boring insects, however, comparatively little is known. Moreover, there appears to be some doubt from the entomological standpoint as to whether they invariably feed on wood substance, and experimental evidence which tends to bear this out will be referred to later.

THE DECAY OF WOOD CAUSED BY FUNGI

The decay of the wood caused by fungi has by common consent been subdivided into two groups, namely, the 'brown' and 'white' rots. It has generally been believed that fungi in the former group attack only the carbohydrates of wood substance and that lignin suffers no depletion, while fungi in the latter category confine their activity to lignin, but it will be seen that these views cannot be substantiated, since there is reason to believe that lignin-attacking fungi invariably attack carbohydrates as well. The first suggestion to this end was made by Hawley and his co-workers (18); experimental evidence is reported

by Falck (12, 9). Further evidence was obtained by the author last year (3), when it was shown that when wood is decayed by *Polystictus versicolor* (Linn.), Fr., in pure culture, lignin is attacked at an early stage, but that later cellulose is also decomposed. It has recently been established at the Forest Products Research Laboratory that the same holds true for wood decayed by *Polyporus hispidus* and *Stereum hirsutum*. Thus experimental evidence would appear to support the view that the lignin in wood cannot constitute the sole food of fungi. It is much more probable that the carbohydrates—and of these principally the cellulose—represent their main source of potential energy. At this stage the views of Rege (25) and Norman (24), that the presence of lignin in wood constitutes an inhibitory factor to decay, can be laid aside in view of the overwhelming evidence to the contrary.

The question now arises as to the ultimate means by which the carbohydrates of wood are made available to fungi, for these substances of high molecular weight must be broken down to soluble substances which will be capable of assimilation. In reviewing the literature on decay by the higher fungi, it is found that the principal degradation processes which are mentioned in this connexion are (1) hydrolysis and (2) oxidation. The promoters of these processes are assumed to be enzymes which are secreted by the fungi. Wood-rotting fungi are known, on the evidence of certain specific tests, to secrete a wide range of enzymes, but it is doubtful as to whether all of these are effective at one and the same time in the degradation of the substrate. If carbohydrates are to be degraded to soluble substances of lower molecular weight it is reasonable to assume that this can best be effected by hydrolysis. In such a degradation it has been established that lignin is but slightly affected, and thus Wehmer (31) has been led to the conclusion that in all types of decay in which lignin is but slightly decomposed, hydrolysis is in the ultimate the dominant chemical process. Chemical evidence in support of this view has been obtained at the Forest Products Research Laboratory (5) by comparing the detailed effect on wood substances of aqueous acid hydrolysis, on the one hand, and decay by *Trametes serialis*, Fr., on the other. The validity of this comparison has recently been questioned by Barton-Wright and Boswell (1), who state that in the advanced stages of dry-rot caused by *Merulius lacrymans* lignin suffers chemical alteration as well as the carbohydrates. These authors suggest that oxidation plays a more prominent part in the decay than hydrolysis. Apart altogether from the merits of this criticism, which need not be discussed here, it is suggested that even in types of decay which bear evidence of the presence of oxidation, such oxidation must be accompanied by hydrolysis, for if it is accepted that wood-rotting fungi derive their energy from monosaccharides, it is impossible that these can arise from complex polysaccharides by oxidation alone. On purely chemical considerations the view is expressed by Heuser (21) that it is still an open question as to whether the oxidation of cellulose with purely oxidizing agents is not associated with hydrolysis. It has been shown above that in certain types of decay lignin suffers marked depletion, even in the initial stages of attack. Wehmer (31) has advanced the view that oxidation

causes this degradation, but since more recent work has shown that this is always accompanied by concomitant degradation of the wood carbohydrates, the suggestion presents itself that if oxidation and hydrolysis are to be regarded as the only effective degradation processes in fungal decay, they may be liable to take place side by side in all such decompositions, although certain conditions which are as yet not understood may secure the dominance of hydrolysis over oxidation, or vice versa, at certain stages of decay.

In the foregoing considerations an attempt has been made to summarize current work on the chemistry of the decay of wood by fungi and to draw from it certain conclusions which may help in the formulation of a chemical approach to the study of wood preservation. Briefly, the problem resolves itself into two heads:

I. The characterization of the chemical reactions which take place during decay.

II. The study of ways and means to treat wood so that the key reactions are permanently inhibited.

THE CHEMICAL ASPECT OF THE DESTRUCTION OF WOOD BY INSECTS

It was mentioned previously that the effect of boring insects on wood has received comparatively little attention from chemists, but it is consistently claimed by entomologists and others that if more were known concerning the feeding habits of these organisms the problem of preserving wood against their attack would be simplified to a considerable extent.

The earlier work on this subject has been summarized by Hawley and Wise (19) and Schorger (29). It has been shown by comparative analysis of sound wood and borings that in virtue of the symbiotic activity of certain micro-organisms, white ants can digest a portion of the carbohydrates of wood substance. This conclusion was arrived at by comparing the proportion of carbohydrates to lignin in sound wood and borings respectively. This proportion was less in the borings than in the sound wood, and the deduction that the carbohydrates were consumed appears to be justified. In the Forest Products Research Laboratory similar experiments have been carried out with the powder-post and death-watch beetles (4). In the case of the death-watch beetle evidence was obtained that the larvae of this insect can apparently utilize the carbohydrates of wood as food, but on comparing sound oak sapwood with the frass of powder-post beetles which was taken from an infected sample of oak sapwood it was found that sound wood and frass were of almost identical composition. It was accordingly concluded that the larvae of the powder-post beetle do not derive food from the cell-wall substance of oak sapwood, but that their source of food was within the cells of the wood. The most recent chemical work on this subject is reported by Falck (10, 11), in which he concludes that the longhorn beetle (*Hylotrupes hajulus*, L.) and the furniture beetle (*Anobium striatum*, Al.) have similar feeding habits to the death-watch beetle.

It can be seen that merely the fringe of the question of insect attack on wood

has so far been touched upon, and that much more detailed chemical investigation is called for. In the case of those insects which feed on the cell-wall substance of wood the chemical approach should be essentially similar to that suggested for fungal decay, but in the case of insects which apparently feed on cell contents another and more obvious line must be followed in order to find out what the food material is, and how it can be rendered unavailable to the larvae concerned.

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SOCIETY AND OTHER NEWS

ANNUAL EXCURSION

At the last Annual General Meeting two suggestions were put forward for the next Annual Excursion, viz. north-east of Scotland (Morayshire) and Ireland (north and south). These were remitted to the Meetings Committee for investigation with instructions to circularize the members with alternative proposals when ready. The Meeting decided that the Excursion should be held sometime during September.

NOMINATION OF OFFICE-BEARERS AND COUNCILLORS

MEMBERS are reminded that nominations for election to office at the next Annual General Meeting may be sent in at any time, but must be in the Secretary's hands by 31 October next. No special form is required, but the nominations must be in writing and signed by two Professional members. Nominations are required for the following:

Office-bearers: President, Vice-President, Editor of Journal, Business Editor, Secretary, Treasurer, Auditor.

Councillors: Three members to hold office for years 1933 and 1934.

A note of the Councillors who retire at the end of this year will be found at the beginning of the *Journal*.

INTERNATIONAL CONGRESS OF TIMBER AND SILVICULTURE

THE Congrès International du Bois et de la Sylviculture held in Paris from 1 to 4 July 1931 was one of a series of congresses organized in connexion with the International Colonial Exhibition. The meetings of the Congress were held in buildings within the Exhibition grounds, so that delegates had every opportunity to visit the numerous stands and pavilions, designed to give a picture in miniature of the diversity and extent of the French Colonial Empire. The organizers of the Congress were in no way to blame if the Exhibition sometimes proved a counter attraction which diminished the attendance in the meeting rooms.

The Congress was divided into four groups: tropical and subtropical timbers, forestry proper, commerce and industry, and the teaching of forestry. Over 150 papers had been contributed, and these were translated into French, where necessary, and printed for distribution to delegates on arrival, an arrangement which enabled them to decide beforehand what sessions were likely to be of special interest from any particular standpoint. It was disappointing to find that many of those who had contributed papers were not attending the Congress in person, and in most instances limitations of time did not allow of more than a summary of each paper being delivered by way of prelude to the discussions. The papers were too numerous to permit of any particular reference in this review; it must suffice to say that the range of subjects covered and the number of distinguished names on the list of authors ensure that the final report, when it appears, will be one of value. In the resolutions passed by the Plenary Session of the Congress stress was laid on the urgent importance of carrying out botanical surveys and of collecting and investigating timbers of potential economic value. Suggestions were made for the organization of production with a view to reducing costs, and for the improvement of loading and transport facilities. Emphasis was laid on the need

for a precise nomenclature, amplified if necessary by botanical names, for all timber species of importance, and it was decided to form a Committee to bring forward proposals on these lines before the next Congress. The section of the Congress which was concerned with the timber trade considered the standardization of the innumerable sizes of timber and types of contract which exist in Europe, and proposed the establishment of international courts of arbitration. It was urged that national committees should be formed to control and direct timber production and imports, and to co-ordinate production with sales.

If the Congress was somewhat overshadowed by the Exhibition, the latter was of exceptional interest to foresters by reason of the fine display of timber in all stages of manufacture. Timber exhibits were a feature of the West Africa, Madagascar, and Indo-China pavilions, but these were of minor importance from this point of view, as a special exhibit of home-grown and colonial timbers was housed in three pavilions close to the Chalet des Eaux et Forêts which served as the bureau of the Congress. The fact that timber was apparently the only raw product which was made the subject of a special exhibit of this magnitude is an indication of the importance attributed by the French authorities to colonial timbers. The Permanent Museum of the Exhibition, which will remain after the rest of the Exhibition buildings are pulled down, also contained a timber exhibit consisting of sixty polished specimen planks of different species mounted as panels round the walls of a gallery. The recently published volume entitled *Nos bois coloniaux*, by J. Méniaud (Agence Générale des Colonies, Paris, 1931), contains a general account of the position of forestry in the French colonies, together with a valuable summary of the information which has been collected to date on the more important timbers. This book served as an elaborate catalogue of the timber exhibit, and is incidentally of value for reference purposes, because it summarizes the results of investigations which have been carried out in France, and gives details of supplies, properties and uses, &c.

Not the least interesting experience of the foreign delegates was the opportunity provided for visiting centres for research in forest botany and forest products. The hospitality of their hosts, and the kindly facilities afforded for inspecting the work of the various institutions, combined to make their visit both pleasant and profitable.

ROYAL HORTICULTURAL SOCIETY'S CONIFER CONFERENCE, 1931

THIS Conference was held in London, in the Society's new hall, on 10, 11, and 12 November. On the morning of the first day the Society's President, the Hon. D. McLaren, who was also President of the Conference, welcomed those attending. The purpose of the organizers was to bring together persons interested in conifers from all aspects, and there were present foresters, botanists, and other experts, as well as amateur and professional gardeners. Each day was occupied with the reading and discussion of numerous papers on the cultivation of conifers, their nomenclature, diseases, economics, and chemistry. There was also an excellent exhibition of conifers, both growing specimens and cut branches, contributed by the Royal Botanic Gardens, Kew, many owners of private gardens, and trade firms. This exhibition was of exceptional interest, and, considering the number of living specimens, it is doubtful if a better one has ever been assembled. It was supplemented by photographs and an exhibit of the economic uses of conifers. A report of the Conference, entitled *Cultivated Conifers*, is being issued and may be obtained from the Secretary of the Society, Vincent Square, London, S.W. 1, price 21s. The report contains the papers read, a description of the exhibition, and list of awards. As the papers likely to be of most value to British foresters one may

mention 'The Influence of Exotic Conifers in Silviculture in the British Isles', by Sir John Stirling Maxwell; 'Random Notes on Diseases of Conifers', by Professor Borthwick, and two papers by Mr. Dallimore—'The Economic value of the Coniferae' and 'Reference List of Conifers Grown Out-of-doors in the British Isles' which gives the scientific names according to the International Rules of nomenclature. Of special interest to foresters also is 'History of Conifers in Scotland', by Mr. F. R. S. Balfour.

FOREST PRODUCTS RESEARCH LABORATORY APPEAL FOR SPECIMEN PLANTS

THE Forest Products Research Laboratory of the Department of Scientific and Industrial Research is gradually accumulating a representative collection of timbers (including home-grown and from the Empire overseas), together with information on their properties and uses. Attention has been mainly directed in the first instance to timbers which are of outstanding economic importance, but it is also desired to collect information on home-grown timbers of minor importance.

The Director invites the co-operation of any land-owners or estate agents who may be in a position to supply specimen planks of the lesser known timbers (native or introduced) or information on their technical properties and the uses to which they have been successfully applied. Particulars of the trees, with any further information of value, should be forwarded to the Director, Forest Products Research Laboratory, Princes Risborough, Bucks. The Director will also welcome the offer of representative specimen planks, and the Laboratory will bear the cost of carriage on any such planks which it is decided to accept.

REVIEWS

Exotic Forest Trees in the British Empire. By R. S. TROUP, C.I.E., D.Sc., F.R.S. Oxford: at the Clarendon Press. Price 20s.

Review by the EDITOR

TWO of the characteristics of our race, the exploring spirit and love of gardens, have made us pioneers in the extension of plants of all kinds beyond their natural homes. It was to be expected, therefore, that we should introduce exotic forest trees under the almost numberless conditions of soil and climate in the British Empire. The Third Empire Forestry Conference recognized the importance of bringing together the knowledge available regarding these trials, and a Committee of that Conference endeavoured to collate the information supplied by the different forest departments. The task proved too great to be completed at that time, and the Imperial Forestry Institute was asked to compile and publish the information available. The present volume is the result. No one better equipped than Professor Troup could have been found to collate and select the material, because his silvicultural knowledge of the forest flora of the Empire, native and introduced, is unrivalled. This volume will be of great service to forest officers everywhere.

There was a time when exotic forest trees were looked at askance, but this phase has passed. It is now recognized by most that while it is foolish to introduce species into a region possessing a rich tree flora of a kind in demand, there are numerous regions capable of growing timber which do not possess suitable indigenous species. The bog of disease is also not now so formidable. Provided a skilful selection is made, cultivation is on rational lines, and the importation of potential diseases controlled, there is no reason why trees should not be freer from disease in their new homes than in their native habitats, and they generally are. Agriculture and horticulture could scarcely continue in many regions if limited to indigenous species, and there is no biological reason why forestry should be so restricted.

The book opens with an introductory chapter which presents data on climate and soil on which to base choice of exotics. The different regions of the world are classified according to temperature and rainfall, amount and distribution throughout the season; an excellent map illustrates this section. There is also a short discussion on soil.

The different species dealt with then follow in alphabetical order, and the notes on each cover the following ground: climate, soil, growth, data, and utilization of timber in the natural habitat of the species; similar data for each region of the Empire in which the species has been tried. The climatic data for Australia and South Africa is defined further in two appendices with maps. There are, of course, numerous gaps in the information available, particularly as regards precision of description of soil types, accessory species which contribute to the maintenance of soil fertility, and statistics of growth, but it is a matter for surprise that so much detailed data are available, and they are marshalled in a concise and lucid manner.

The space allotted to the species used in Great Britain might have been usefully extended to include the extensive information available regarding them, but other publications are, of course, readily available for our species. It is interesting to note

that, judged by the number of species tried, the most important exotic genera are: *Eucalyptus*, *Pinus*, and *Acacia*.

No doubt many forest officers would have liked the book interleaved with blank sheets, so that additional data might have been entered, but this would have added unduly to the bulk of the book, and the use of India paper would have greatly increased the cost. The production of the book leaves nothing to be desired.

Improvement of Woodlands. W. E. HILEY, M.A. Country Life, Ltd., London. Price 10s. 6d.

Review by the EDITOR

THIS book is written primarily for owners of woodlands, but all who are interested in British forestry should read it, because the present state of private forestry in this country is a matter of concern to all who know the position. The area felled during and immediately after the War could only have been made good by one of those bursts of planting fervour which marked the end of the eighteenth century and the second half of the last century, but instead there has been a steady decline in the annual acreage planted by private individuals. The post-War activities of the Forestry Commission may have tended to divert attention from the state of private forestry, but the Acland Report, on which the Commission was founded, postulated that the existing 3,000,000 acres of private woodland be maintained, while the Census of Woodlands taken in 1924 showed that over one quarter was then scrub, and another quarter of very low productive capacity. If the minimum national requirements laid down by the Acland Report are to be met, either there must be a revival in private forestry, or the scale of State activities increased. Whatever may be one's views on the desirability or otherwise of State activity, there is no doubt that the special problem of the improvement of private woodlands can be solved by simpler organization through their present owners than through the State. Moreover, vigorous private forestry can do much for State forestry, both in stimulus and in pioneer work, such as has been done in the past by private owners. Mr. Hiley's book, therefore, deserves the closest attention.

The decline of private forestry is due to many causes, which can, however, be grouped into three categories: economic—the belief that forestry is not profitable, or lack of capital for long term investment; lack of interest; and lack of knowledge. This book deals with all these reasons.

As one would expect, Mr. Hiley deals very thoroughly with the economic side. A very informative chapter goes into the various questions connected with the taxation of woodlands, which brings out very clearly how favourably woodlands are treated in this country, compared with other kinds of property, and also with woodlands in other countries. This chapter merits careful study by owners, and those in a position to influence them, because here is an inducement to private forestry which has not been fully realized by those concerned.

An effort is made to interest the apathetic by painting in attractive colours the joys of the creation and tending of woodlands: 'without a nursery half the fun of cultivation is lost. A peculiar pleasure attaches to raising plants at home and this pleasure is intensified if seed collected in home woods is grown into trees.'

Although the book does not profess to deal exhaustively with forestry technique, the major subjects are dealt with in varying detail: Choice of species, nursery work, natural regeneration, thinning, and simple management. Mr. Hiley has utilized recent information so that the book is an advance on the older British works dealing with these subjects.

Special mention should be made of the Hon. N. A. Orde-Powlett's chapter on 'How to Combine Sport with Forestry'. His views on forest management are orthodox, indeed more so than some professional foresters, and he does not do violence to what the professional forester considers sacred. This is a subject calling for closer study by foresters.

This book is a reasoned appeal for a revival in private forestry. We hope that revival will take place.

Regional Survey and its Relation to Stocktaking of the Agricultural and Forest Resources of the British Empire. By RAY BOURNE. *Oxford Forestry Memoirs*, No. 13, 1931.

Review by W. H. GUILLEBAUD

HAVING regard to the fact that the forest resources of the Empire lie for the most part in territories which have only comparatively recently been explored, the process of taking stock must obviously precede any attempt at intensive or even efficient management. But a stocktaking of forest *per se* covers only part of the problem. In all countries, however highly developed, there exists a constant tension between the respective spheres of forestry and agriculture; in many of the Colonies this is a formidable problem. For lack of adequate knowledge, forest land may be converted to agricultural uses only to prove unsuitable, and to revert after a short time to a wild state, usually of a wholly uneconomic nature. It is, as we understand it, the somewhat ambitious object of the author of this Memoir to provide a remedy for this state of affairs, a remedy which shall consist in providing the knowledge of Nature's processes which is now lacking, and so enabling each forest authority not merely to state what its forest resources are and where they lie, but also to justify its claim to them as land which should not be alienated to other uses. To achieve this end an objective method of locality assessment is clearly required, and here the difficulties begin. Ordinary extensive methods of survey will give information as to the main types of forest, will show where exploitable timber is located, and differentiate between land under scrub, under agriculture, and under forest, but will not go far towards determining the most scientific form of utilization in any given instance. It is presumably because Bourne is so convinced of the importance of such knowledge that he dismisses extensive methods of survey in a few words, and proceeds with his far more elaborate plan of intensive sample surveys based on what he terms the comparative study of localities. In Bourne's view almost complete information as to soil productivity and soil development could be obtained by comparing a sufficient number of equivalent soils on similar sites under different forms of utilization, e.g. under grass, arable, forest, and individual types within the forest. It is recognized that this must involve intensive local surveys to be carried out by a team of specialists including experts in botany, ecology, geology, soil science, forestry, &c. Unhappily, team work of the sort contemplated by Bourne is a very difficult thing to achieve in practice; the problem of leadership in particular is likely to be a thorny one. The comparative method of locality research is also not without its dangers, the crux of the method lies in the correct identification of equivalent sites; any error in this respect may well prove fundamental.

It would be clearly impracticable to examine intensively any great stretch of country, hence the methods proposed can only be applied to carefully selected sample areas. A description of such a sample survey is given in Chapter II and in the Appendix, which together comprises more than four-fifths of the entire Memoir.

This survey was carried out on a strip of country about a mile in width lying between

Burford, in Oxfordshire, and Crowthorne, in Berkshire, a distance of about forty-three miles. The strip was photographed from the air, using a vertical camera, and a picture of the country thus obtained on a scale of about 6 inches to the mile. A tracing from the photograph was made showing the roads, field boundaries, &c., and the boundaries of the geological formations, so far as they affected the strip transferred to the tracings. A field survey of the area was then carried out, the tracings being used for field sketching and the aerial photographs as maps. As a result, the author was able to map the area into regions, sites, soil types, and also the farm lands into ten classes with reference to the raising of sheep. The regional classification of land is, as Bourne points out, a very old one, but as a rule the geographer, who has made the most use of the concept of regions, is content with major subdivisions, and would disregard the minor changes from point to point, which are, however, so important when it comes to the effect of local conditions upon agriculture or forestry. The system proposed in the Memoir is based on topographical subdivisions, the importance of the geological structure being emphasized by the introduction of the name of the geological formation into the title of the majority of the regions. An example will illustrate this point. The area where the strip survey crosses the London Basin is divided into six regions, which are named as follows:

- (1) E.P. Reading Outcrop.
- (2) U. (1) London Clay I (London Pebble Bed).
- (3) U. (1) London Clay II (London Clay).
- (4) E.P. London Clay III (London Clay, Plateau Gravel).
- (5) P. (4) Bagshot Outlier.
- (6) E.P. London Clay IV (London Upper Clay).

The letters refer to the topography: E.P. = Low Escarpment and Undulating Plateau Regions. U. (1) = Undulating Valley Regions. P. (4) = Hill Outlier in a Plateau Region. In all, the author recognizes forty-five distinct regions in the strip surveyed (the strip was deliberately chosen so as to traverse as diverse ground as possible). In connexion with the use of geological names for describing regions, Bourne makes a statement that he had had occasion to examine soils in Europe, India, and Africa under a great variety of conditions as to climate, topography, and geology, and that he cannot remember having ever seen a soil which did not show some features essentially attributable to its geological origin. This emphasis on the importance of geology in relation to soil forms a timely corrective to the views of some soil scientists who tend to exalt the climatic factor to the virtual exclusion of geology.

A site is defined as an area which appears, for all practical purposes, to provide throughout its extent similar local conditions as to climate, physiography, geology, soil, and edaphic factors in general, and it is clear that the recognition of all the sites in a given region must require very close and accurate study of local conditions. It was owing to the lack of the necessary specialist team work that there are few if any of the regions for which the author has felt equal to defining all the sites. Bourne's provisional classification of sites in the Reading Outcrop Region of the London Basin is as follows:

Lower Escarpment

or Outer Ridge Sites. Sand over Chalk (S/Ch), Sand Clay with Flint (SCF), Reading Clay (RC), Reading Sand over Clay (RS/RC), Reading Sand (RS).

Main Escarpment Sites. Reading Sand over Clay (RS/RC), Reading Sand (RS), Reading Sand with Clay Layers (RC/RS/RC).

Dip-slope Sites. Reading Sand (RS), Reading Sand with Clay Layers (RC/RS/RC), London Pebble Bed (LPB).

Valley Bottom Sites. Alluvium (see p. 149 of Memoir).

It will be seen that the region is subdivided into certain topographical units, and that these are further split up according to soil type. Thus the recognition and mapping of the individual soils must precede any attempt at site classification. The author actually names fifty-three types of Drift Soil and fifty-two types of Residual Soil as occurring within his Survey.

Within any one region equivalent sites are found to recur repeatedly, and each region tends to have its own typical association of sites which changes more or less completely when the boundary of an adjoining region is crossed.

We can only touch here on some of the many interesting points made by Bourne in his account of his experimental survey. The great value of aerial survey is well illustrated by the beautiful photographs which are appended to the Memoir. It may be observed, however, that the plans accompanying the strip photographs are somewhat over-packed with detail, and consequently are difficult to follow. A heavier marking of the regional boundaries on the strip photographs would also have been an improvement. The relation between the soils and current as well as past agricultural practice is frequently referred to in the course of the Memoir, and it is surprising to find how much information has been brought to light. In the study of the Chiltern beech woods, nine woodland types were recognized, each of which can be identified edaphically and by the differences to be observed in rate of growth, form of crop, development of ground flora, and in the nature of the regeneration. Neither soil survey nor vegetation survey alone would have sufficed for an adequate classification of the woods.

In conclusion, whatever views may be held as to the practicability of some of the proposals in this Memoir there can be no question as to the value of much of the original work which it contains. The type survey carried out by the author to illustrate his conception of classification into regions with their attendant site complexes forms an important contribution to the difficult problem of locality assessment, for which the author deserves the gratitude of all concerned in this branch of soil science.

Silvicultural Research Manual for Use in India. Vol. I: General. By H. G. CHAMPION. Vol. II: Statistical Research. By H. G. CHAMPION and I. D. MAHENDRU. Government of India Central Publication Branch, Calcutta, 1931. Price 34s. 3d.

Review by the EDITOR

THE Indian Forest Service were pioneers in silvicultural research in the Empire. Particular attention was paid to increment sample plots, and the methods elaborated for their measurement were followed in part when such work was started in this country in 1920. Since that date methods of experimental silvicultural research in nurseries, artificial regeneration, and sample plots, have received intensive study by the Forestry Commission Research Officers. The whole technique of experiment has had to be reconsidered in the light of the post-war advances in plot replication and statistical analysis elaborated for agriculture by R. A. Fisher, 'Student', Maskell, and others. This work was incorporated and modified for silviculture shortly after introduction, and *Forestry Commission Bulletin*, No. 11, published in 1928, presented the results of the first silvicultural experiments carried out by the new technique. The two publications reviewed here have been under consideration and preparation since 1928, and Volume I incorporates some of these new methods of technique; and also recent advances in other fields, for example, ecology. The publication of these two volumes ensures that the now

extensive organization for silvicultural research in India will proceed in the light of recent advances, although in a rapidly developing subject constant review is necessary. This work will also be of great help to silvicultural research elsewhere.

Volume I deals with general experimental methods, and consists of two parts: Part I, General Considerations, and Part II, Typical Problems. The method of presentation is to take each subject, make a general statement, and illustrate with one or more examples. Part I is, therefore, really a collection of hints on procedure and covers a very large field, even to the method of preparing results for publication, and correction of proofs, an important but frequently inadequate equipment of researchers. The method of presentation does not make for ease in reading, but it undoubtedly will be of greater help to the worker than a more general descriptive method.

The introduction of plot replication is a distinct advance, and if put into operation will increase the reliability of future work. Single plots have their place in experiment, namely, where comparative treatments are not being studied, but elsewhere, beyond the preliminary stages of investigation, all treatments should be replicated in each individual experiment, the experiment should be repeated in each set of conditions in which the results are to be applied, and over a range of seasons. The more variable the site conditions, the greater is the need for replication, for example, replication under forest conditions is even more necessary than in an experimental garden.

The need for replication is independent of statistical analysis, but the requirements of modern methods of statistical analysis controls the method of replication. Even although there is no immediate possibility of applying methods of statistical analysis, the plot technique should be such as to enable this to be done later. In the chapter dealing with statistical analysis of Latin Square Chessboards and Randomised Blocks, it is incorrectly stated that the standard error so obtained is the standard error of the means instead of the mean difference. This explains two footnotes querying the use of standard error so obtained, instead of $\sqrt{2}$ times the error.

Consideration will show that the standard error is derived from a total variance of the differences between the mean of all treatments and the individual yields (see *Forestry Commission Bulletin*, No. 11, p. 179 (*e*)), and is thus a standard error of the mean difference, and is applicable to the differences between treatments.

Part II is of general interest and deals with typical problems of distribution, locality, and types of forest, the development and character of trees and crops, methods of management, afforestation, natural regeneration, artificial regeneration, tending, and protection. This section not only reviews literature and lays down methods of research, but gives a picture of Indian forest problems. No detailed criticisms can be attempted here, but in discussing methods of soil study it would have been useful to refer to the recent development of profile studies, both for field interpretation, and as a basis for detailed laboratory study.

Volume II deals with the research carried out by forest mensuration methods. Much work has been done in India in obtaining growth and increment data, but the immensity of the problem with so many species and conditions justifies the care taken to make this comprehensive guide to methods. The only criticism which is made is the failure to introduce methods of plot replication into thinning investigations. From the introduction of replication into forest investigation in this country, it was realized that it would have to be applied to thinning plots. This work in this country has had to be done largely in small private plantations where a sufficient area is rarely available, hence it has only been possible to secure replication to a limited extent to date. A recently issued departmental memorandum on the subject by the South African Forest Research

Division has brought in these methods after preliminary trial following advocacy by the reviewer in South Africa in 1929. There is no doubt that we will not get reliable comparative thinning data until investigations on these lines have been carried out, and it would have been a distinct advance if this revised code had described and introduced the method into India. Perhaps this will soon come. It would also have been of interest and of importance to sample plot procedure in India at a later date if methods had been laid down for the accumulation of data on the applicability of the Form Quotient formulae to Indian coniferae.

This manual of forest experimental methods is the most comprehensive which at present exists, and the authors are to be warmly congratulated on what is a monumental work. It bears the imprint of Mr. H. G. Champion's wide scientific and forestry knowledge and experience. The labour must have been increased by the necessity of making it the expression of the experience of many individuals, but its value is thereby increased. It is profusely illustrated by graphs, diagrams, and beautiful photographs of work in progress.

The Timber of Home Grown Douglas Fir (Pseudotsuga taxifolia Brit.). Forest Products Research Bulletin, No. 10.

Review by J. T. SMITH

LITTLE more than a century ago the first seeds of Douglas fir were brought to this country, but plantations of size have been formed only within the last seventy years. The timber is already on the market in relatively unimportant quantities. The Forestry Commission have planted since 1919 approximately 30,000 acres of this species. According to their own records (*Forestry Commission Bulletin*, No. 10), made from private plantations, the tree reaches in this country a mean height in first quality crop of 110 feet at 50 years, and at the same age has produced a yield varying from 6,000 to 8,000 cubic feet per acre. In its natural habitat abroad the trees grow for 200 to 300 years and have reached a height of 380 feet with a maximum diameter of 15 feet. The issue therefore of *Forest Products Research Bulletin*, No. 10, in August 1931, presenting a detailed report upon the characteristics of the wood as grown in this country to date marks a definite stage in the life of the tree here. The *Bulletin* is illustrated with photographs, charts, and diagrams, and provides a wealth of statistical data comprising the results of careful examination of the structure, seasoning, strength, preservation, working quantities, grade, and uses of the timber.

The results on the whole are disappointing. As indicated above, any tests as to quality must necessarily be of a preliminary nature. The Laboratory staff have made a praiseworthy effort to indicate the possibilities of the tree and to compare the timber with that grown abroad. It is not their fault that the trees tested averaged 4 to 5 rings per inch, while Canadian Douglas, as used in this country, is rarely less than 8 rings and more frequently 12 to 16 rings per inch. The samples tested were drawn from three widely differing localities, viz. Perthshire, Argyllshire, and Wiltshire, and appear to have consisted of timber well above the average quality so far available in this country. In the general summary of results it is stated that home-grown Douglas fir yields timber of fair mechanical properties, especially that grown with not less than 6 to 7 rings to the inch, and preferably 10. The *Bulletin* does not state that over 95 per cent. of the timber so far available is not within that description. It is indicated that locality affects the strength of the timber. The wood seems to be lighter in weight than Oregon or B.C. Douglas. On the information given in the *Bulletin* it is doubtful whether it is

worth while kiln seasoning. It does not absorb readily, and satisfactory absorption apparently involves incising and considerable expense. The timber works moderately well but involves more care with knives, &c., and therefore also additional expense. The section dealing with the grade and uses is the most important one and the least prominent. Attention is specially drawn to the prevalence of knots and the rapid growth of the tree. It is unfortunate that the question of defects is not more fully discussed elsewhere in the Report. Most of the tests appear to have been made with short sections of timber (except in the case of sleepers and planks, the photographs of which show extraordinary low grade). The figures given of comparison with the timber of other species are less valuable owing to the absence of data relating to timber of equally rapid growth. The uses indicated have all been tried. They are, it seems to the reviewer, the uses to which cheaper classes of timber are put in this country, and in no instance is it stated that the consumer is being satisfied.

It is clearly indicated throughout the *Bulletin* that home-grown Douglas fir, properly grown, may some day equal, under test and be employed for the same purposes as that imported from Canada and elsewhere. It is up to the grower meantime.

Forest Trees and Timbers of the British Empire, I. Some East African Coniferae and Leguminosae. By L. CHALK, J. BURTT DAVY, and H. E. DESCH. Clarendon Press, Oxford, 1932. Price 5s.

Review by the EDITOR

THIS publication is the first of a projected series dealing with the forest trees and timbers of the British Empire. The species now dealt with are: *Juniperus procera* Hochst, *Widdringtonia whytei* Rendle, and *W. juniperoides* Endl, *Podocarpus gracilior* Pilger, and *P. milanjanus* Rendle, *Afzelia quanzensis* Welw., *A. africana* Smith, and *A. bipindensis* Harms, *Baikiaea plurijuga* Harms, *Copaifera coleosperma* Benth., *Piptadenia buchananii* Baker, and *P. africana* Hook. f., *Pterocarpus angolensis* D.C., and *Pterocarpus stevensonii* Burtt Davy.

The general plan for each species description is to give the systematy, botanical characters, distribution, and macro- and microscopic characters and uses of the timber. There are illustrations of the botanical characters, a habitat photograph, and micro-photographs of the timbers.

In some instances notes are given on regeneration, natural and artificial. Interest would be extended if more silvicultural data of this kind were included in future publications, and these could no doubt be readily obtained from officers on the spot. For example, the two *Podocarpus* species are interesting silviculturally on Mount Kenya. In the cedar forest on the western slopes, *P. gracilior* is a much larger tree than *P. milanjanus*, but the latter regenerates more freely, often under *P. gracilior*. The natural regeneration of the more desirable species is, therefore, rendered difficult. *P. milanjanus* is a much larger tree in the *Ocotea* zone, where it occurs sporadically.

The authors are to be congratulated in a good beginning of an immense task, and the Clarendon Press for a beautiful production.

The Density of Australian Timbers, a Preliminary Study. By H. E. DADSWELL. Commonwealth of Australia, Council for Scientific and Industrial Research, Division of Forest Products, Technical Paper, No. 2. Melbourne, 1931.

Review by S. H. CLARKE

IT is well known that both the weight and volume of a block of wood are influenced by the moisture content, and that the failure to recognize this fact has considerably lessened the value of many results published during the last fifty years. Even where attention has been given to moisture content, previous workers have based their calculations of the density of wood on no less than eight different methods, each capable of yielding a result different from the others. Consequently, at the beginning of a series of determinations of the density of Australian timbers the author considered the merits of the various methods that have been employed and decided in favour of the ratio of

$$\frac{\text{oven-dry weight}}{\text{saturated volume.}}$$

It is pointed out that by this method all errors due to shrinkage or collapse (to which certain Australian timbers are prone) are eliminated, and the advantage is gained that any investigator may obtain comparable results.

The procedure followed in determining the density of a given sample was to cut three adjacent cross-sections $\frac{1}{4}$ to $\frac{1}{2}$ inch in thickness and at least 2 inches from one end of the sample. These were trimmed to approximately 1 inch by $2\frac{1}{2}$ inches. The moisture content of the two outer samples was determined, and on the assumption that the central sample was in a similar condition was calculated from the formula:

O.D. wt. of central sample

$$= \text{original wt. of cent. sample} \times \frac{\text{O.D. wt. of outer samples}}{\text{Original wt. of outer samples.}}$$

Experiments showed that the oven-dry weight of the wood calculated in this way was reliable. The saturated volume was determined by immersing the samples in cold water, it was found that five or six days was sufficient for this purpose, even when the wood had suffered from collapse.

The possibilities of the method for general and identification purposes were investigated, and the opinion is expressed that with the narrowed range within a species by using this standard method, density may prove to be a useful factor in identification. In the opinion of the reviewer, however, while knowledge of density is invaluable as an indication of mechanical properties, its value in identification is likely to prove of limited application.

An unusual feature in the pamphlet is the expression of the ratio $\frac{\text{oven dry weight}}{\text{saturated volume}}$ in terms of pounds per cubic foot. In the past, many workers—the reviewer included—have referred to the results yielded by this ratio as specific gravity. A moment's reflection will show that this practice is not strictly correct, for, although this invaluable ratio is a function of specific gravity, the actual weights and volumes used do not exist at the same time. It seems probable that even more confusion may arise from the conversion of the results to pounds per cubic foot, as this form of expression is the one used chiefly by the timber user. This matter is receiving the attention of forest products research workers throughout the world at the moment, and until a unanimous

decision is reached it would be best to qualify 'specific gravity' or 'density' based on the ratios

$$\frac{\text{oven dry weight}}{\text{saturated volume}} \text{ or } \frac{\text{oven dry weight}}{\text{volume as tested}}$$

every time they are mentioned.

The publication of the promised series of results should certainly bring a valuable addition to our present knowledge, and it is to be hoped that it will soon be accomplished.

The Chemistry of Australian Timbers, Part I. *A Study of the Lignin Determination*. By W. E. COHEN and H. E. DADSWELL. Commonwealth of Australia Council for Scientific and Industrial Research Division of Forest Products. Technical Paper, No. 3, Melbourne, 1931.

Review by W. G. CAMPBELL

THIS paper is the first of a series on the chemical composition of Australian hardwoods, and is concerned in the first place with one of the most important aspects of wood chemistry, namely, the sampling of woods for analysis. The authors have demonstrated that when woods contain large amounts of brittle, resinous extraneous material, serious errors are likely to arise in sampling.

Prior to analysis, wood must be ground to a flour of uniform particle size. Standard practice has hitherto involved the use of 80-100 mesh flour, but as the resinous material in many Australian woods is readily reduced to a fine dust during grinding operations, wide variations in the amounts of this material which will be retained on a 100-mesh screen are bound to occur. In other words, the 80-100-mesh material is not truly representative of the original wood. The authors suggest that this difficulty can be overcome by grinding the entire sample to pass a 100-mesh screen before carrying out the analysis. This method has proved successful with Jarrah (*Eucalyptus marginata*), Red ironbark (*E. sideroxylon*), and Mountain ash (*E. regnans*), and it has also been applied, for comparative purposes, to Canadian spruce and Hemlock. It remains to be seen, however, whether it will be possible to reduce entire samples of all woods to a flour of such small particle size, for it is not unlikely that difficulty would be experienced with very resinous samples of pitch pine, for example, and with a wood like bald cypress, the sawdust of which is so waxy that even 80-100 mesh material can only be prepared from it with difficulty.

The principal value of this paper lies in its pertinent criticism of the lignin determination in wood. Microscopic observation reveals that preliminary extraction of samples with alcohol benzene (2:1) does not remove the extraneous resinous material, and this, in consequence, is estimated along with lignin. The error introduced here is a direct function of the resin content of the wood, and is naturally most accentuated in timbers which like the Australian eucalyptus contain large amounts of kino. The authors have found by experiment that kino can only be removed by a preliminary extraction with a weak solution of sodium hydroxide, and suggest that if such an extraction were applied universally prior to the lignin determination proper, much more reliable results would be obtained, for even in the two Canadian softwoods examined, alcohol benzene fails to remove all extraneous material. It is claimed that extraction of wood samples for eighty minutes with alkali of strengths up to N/8 causes no degradation of lignin, but the paper rightly concludes with the note that the work will not be complete until the nature of the substances that are removed by the alkaline treatment, together with that of the extraneous substances, is determined.

NOTICES

Preliminary Observations on Scottish Beechwoods. By A. S. WATT. *Journal of Ecology*, xix, No. 1, pp. 137-57; No. 2, pp. 321-59, 1931.

IN this contribution Dr. Watt extends his investigation of British beechwoods to the north-east of Scotland. The results are preliminary, but certain interesting points emerge. The beech sets seed as far north as Caithness, and on Strathdon survives up to an altitude of 1,350 feet. In the north-east of Scotland it has been commonly used for shelter belts, and in these two types are defined the *Deschampsia* type, and the *Holcus* type. These are correlated with exposure to the south-west wind, the *Deschampsia* in the more exposed, and the *Holcus* in the less exposed sites. On steep, sheltered slopes a herbaceous type was also found. The grassy beechwoods are related to heath and the dry oakwood; the herbaceous beechwoods to the damp oakwood of the lighter loams. It is concluded that both will eventually degenerate to heath, through the accumulation of raw humus on a podsol in an oceanic climate.

Bibliographia Universalis Silviculturae, I. Dania. København, Leven and Munksgaard, 1931.

THIS bibliography of Danish forestry literature to 1925, prepared by A. Oppermann and V. Grundtvig is the first fruits of an undertaking begun in 1903, when Philipp Flury proposed at the fourth meeting of the International Union of Forest Experiment Stations that an international forestry bibliography be prepared. The project has had a chequered history, but at the seventh meeting in Stockholm in 1929 the publication of an international forestry bibliography was laid down as one of the principal tasks of the Congress of Forest Experiment Stations. Denmark is to be warmly congratulated on leading the way in this important work. The arrangement is a simple one, the authors being arranged alphabetically, without cross reference by subject.

Forsøk med vestamerikanske traeslag. OSCAR HAGEM. Medd. Nr 12. Vestlandets forstlige. Forsøksstation, Bergen, 1931. (German summary.)

THIS volume dealing with experiments, in Norway, with conifers from North-West America is important, because it not only gives the results of nursery trials but discusses principles on which the introduction of species should be based. The chapters deal with: climate, tree limits, and provenience; temperature and rainfall in West Norway; temperature and rainfall on the north-west coast of North America; methods of procedure; and the results for individual conifers, which include *Picea sitchensis*, *Pseudotsuga taxifolia*, *Tsuga heterophylla*, and *Thuja plicata*.

The modern view is taken that close matching of climate, between the place from which seed is obtained and the place where it is used, is necessary because comparatively small changes in climate influence climatic races of a species. The aim is, therefore, to use each race in its climatic optimum. The climatic factors used are: summer heat, the vegetation period when the temperature is 7.5°C. and over, winter cold and rainfall. This basis is applied to a comparison of the coasts of North-West America and West Norway, and races of the principal conifers on the former have been tried on the latter.

The results for Sitka spruce are of most interest. As in this country, this species from

Washington and California is useless for Norwegian conditions. Similarly, seed from the south of British Columbia, south of latitude 52° , is not hardy in the nursery. Proceeding northwards the hardiness increases, but it is of interest that until the Alaskan coast, 57° to 58° , is reached the seedlings in the Norwegian stations are not quite hardy. Unlike this country the Queen Charlotte Island seed is not suitable.

The coast forms of Douglas fir have not given very satisfactory results, but some of the interior forms, e.g. from Mount Ida are promising for East Norway.

Pruning Experiments on Second-growth Stands of Douglas Fir. S. R. SCHENSTROM. *The Forestry Chronicle*, December, 1931.

THE approach of the State plantations in this country to the cleaning and pruning stages makes the subject of pruning a live one. It is now generally realized that pruning of final crop trees will be necessary to produce satisfactory material.

The results stated in this article are based on limited data, and should be considered suggestive rather than conclusive, but several are of interest. The trial was carried out at the Cowichan Lake Forest Experiment Station, B.C.

1. The natural regeneration of Douglas fir in cut-over stands on British Columbia, generally results in too low a stocking to produce clear timber. Surveys have shown that 62 per cent. of the areas have stockings of 1,000 trees or less, while data is presented to show that 2,500 at 20 years is necessary to secure a low percentage of stout branches.

2. Early spring is recommended as the best time for pruning, partly to avoid enlargements of the wounds by frost, and partly to avoid the season when most wood-destroying fungi fructify.

3. The age of the trees pruned was about 20 years, their average height about 38 feet, and the number of coniferous stems per acre about 1,700.

4. The pruning was done with the help of a ladder, the top rung being replaced by a cross-rope, and the ends of the uprights bound with sacking to prevent injury to the tree. A hand-saw was used. The limbs were not cut close to the bole, but immediately outside the basal bark-collar.

5. The average time taken per tree to prune within reach of the ground was 2.9 minutes, and data are presented for ladder pruning, e.g. to 20 feet took in all about $13\frac{1}{2}$ minutes per tree. A graph shows that the cost of pruning rises steeply with height pruned, the cost per tree for 10 feet being approximately 5 cents and for 25 feet, 25 cents.

THE GROWING TREE¹

BY PROFESSOR J. H. PRIESTLEY

(University of Leeds)

BUDS AND GROWTH

THE growth activities of the tree seem ripe for reconsideration, in the light of the fact that it can now be stated with great confidence that each spring growth is renewed in the bud and that, as apical growth leads to extension growth of the shoot, radial growth commences in the new leaf primordia at the shoot apex, and from thence spreads down the tree.

That the resumption of growth of the cambium thus depends on the buds has been clearly established this year by the use of a new method. As the cambium becomes active again in the spring, the contents of its cells become relatively more liquid and the walls thinner and more plastic; whilst in this condition the bark readily peels from the wood, separation taking place at the cambium. As cambial activity continues, a thin film of soft, plastic tissue is laid down over the surface of the old wood, practically all the first cells cut off from the cambium being additions to the wood. When the bark is peeled off, it is possible to 'strip' these new, soft tissues from the surface of the old wood by the simple means of scraping the surface. On the twigs this may be done with a knife, but on the trunk the thick bark is best cut with a chisel and mallet, and the surface of the wood scraped through the narrow incision in the bark with a tool such as a screwdriver, as in this way less damage is done to the tree. By this method it is possible to obtain samples of the new tissues formed from the cambium in any quantity and with comparative ease. The scrapings may be fixed in ordinary fixing fluids, such as chrom-acetic acid, and after washing be kept in alcohol until time is available for their examination, which is of great advantage, as thus large quantities of material may be collected from the trees during the brief period when the method is available. Some thirty hardwoods and some six softwoods were examined in this way during the spring of 1932, and in no case was any exception found to the rule that cambial activity on the surface of the old wood begins beneath the buds and spreads basipetally down the tree.

This general conclusion is clearly of the greatest importance to the understanding of radial growth. The snag left in pruning, when a piece of stem is left above any living bud, is obviously due to the failure of cambial activity to start afresh in the piece of stem projecting beyond this uppermost bud. The whole technique of silviculture also depends upon this same fact. Close planting means that the lower lateral branches are in deep shade; the upper buds

¹ Abstract from the Presidential Address to Section K and Department K*, British Association, York, 1932.

in the light start growth first, and under such conditions the lower shaded buds may never start into growth at all.

On a branch in which the buds have not resumed growth, the cambium will not become active either; its cells never resume the liquid, plastic state, the bark does not slip on the branch, and consequently, as the bark on the main stem moves outwards owing to the expansion of the living growing tissues within, the bark around the base of the branch is put under a great strain. From the wood of such a dormant branch, water is withdrawn into the active growing regions of the tree; the branch becomes dry and brittle, and as the strain of the bark pressure around its base increases, it is probably snapped off. The stump of the branch is then buried by the continued growth of the tissues of the main stem until only the scar in the bark and the folds around it are left as witness of the former presence of the branch (1). The stump forms, of course, a 'knot' in the timber, and the somewhat different properties of hardwood and softwood knots are largely accounted for by the different habits of growth of these trees. In the softwood, with its regular whorls of branches, the lower shaded branches resume radial growth very slowly, whilst cambial activity spreads rapidly down the main trunk from the upper regions in the light; consequently new tissues are being added to the main stem and are running around the wood of the previous year of the branch without making any union with it, union only being made later when the cambium of branch and main stem are growing simultaneously. As a result the knot of the softwood may lie comparatively loosely in the plank, because the wood of branch and main axis have no intimate union in the tangential plane represented by the plank. On the other hand, in the hardwood, with their less regular branching habit, growth is usually resumed about the same time in branch base and main axis, so that subsequently the knot in the plank is firmer, because the wood increment was formed simultaneously and was continuous from the branch base to the surrounding surface of the main stem.

RADIAL GROWTH

The strip method is so new that it is too early to indicate even its possibilities to the forester, but certain points of interest are already emerging. In certain hardwood trees, e.g. oak, elm, ash, and sweet chestnut, radial growth beneath the buds is resumed with extraordinary rapidity, so that even before the buds are well open, a new radial increment of wood is forming right down to the base of the trunk. In most trees, on the other hand, radial growth on the main axis is resumed much more slowly; for example, in beech, birch, and alder for some weeks radial growth can only be recognized at the base of the buds, no traces of it appearing over the old wood, even of the twigs, until extension growth commences in the new shoots, although the leaves on them are well expanded before this. In others, as in the arborescent *Rosaceae*, sycamore, horse-chestnut, willows, poplars, &c., new radial growth begins relatively rapidly on the twigs, but then spreads more slowly to the main branches and trunk. It is very suggestive to note that the first type of tree, in which the new wood formation

spreads downward so rapidly, includes all the common examples of 'ring porous' wood found in this country, whilst the other types have characteristically 'diffuse porous' wood. These differences must be connected with differences in vessel differentiation, and these will certainly reveal many further points of interest as they are studied by the new method.

In the strips from the hardwoods it is possible to see every stage in the differentiation of vessels. This process, known to begin at the leaf-base, is then seen to spread downwards as the impetus to radial growth precedes it down the tree. No new vessels are added at lower levels in branch or trunk, which are not in direct connexion with the vessel system differentiating in the new shoot, though, of course, along the length of such vessel systems occasional cross-walls will have been left unbroken. This means that the whole vessel system of the hardwood tree must be regarded as terminating upwards in the successive crops of leaves or leaf-scars; the vessel system of the root cannot be discussed from this standpoint until more work has been done upon it.

A study of the strips during vessel differentiation impresses upon the observer the great speed at which the expansion of successive vessel segments must take place, including the perforation of end-walls. Expansion and perforation occur whilst the walls are still unthickened, whilst the subsequent appearance of the characteristic thickening, pitting, and lignification follow rapidly on the lateral walls and the remaining rim of the cross-walls. It seems impossible, in the light of these observations, to regard the cross-wall as gradually digesting, its perforation would appear rather to be the result of the rapid expansion of a short differentiating element in which the cross-walls are relatively transverse, and which are consequently put under great strain. More oblique walls are less strained, and either develop a series of small perforations in the region of areas previously penetrated by protoplasmic connexions or remain unperforated as oblique ends to the vessels.

Some estimate of the lengths of vessels has been obtained in the course of this work, and it is a very suggestive fact that the vessels are very much longer in the ring porous type of wood, in which also the downward differentiation seems to be comparatively more rapid. In well-grown trees of ash, elm, and oak, vessel lengths of more than 10 feet are the rule in the trunk, and measurements up to 25 feet have been obtained by methods which probably give minimum rather than maximum values. In the diffuse porous type of wood the vessels are very much shorter. These facts may be of considerable practical importance with regard to the behaviour of felled timber, for reasons which are briefly indicated later.

HARDWOOD AND SOFTWOOD

The differences between hardwood and softwood require reconsideration in the light of this new method of study. In the softwood, cambial activity spreads downwards with great rapidity from the buds, and always more rapidly down the main axis and the well-lit branches than down the shaded branches. Opportunities for study of stands of well-grown timber have been too few up

till now, but there is an indication that radial growth works much more slowly down even the main axis of a heavily shaded tree. On the whole, the basipetal cambial activity spreads downwards more rapidly in the softwoods, and this may be connected with the fact that the individual cambial elements are relatively extremely long. The dimensions of these softwood cells, called fusiform initials by I. W. Bailey, are really extraordinary. They form long, radially compressed threads, with very pointed ends. These threads divide repeatedly by tangential walls, that is by walls parallel to the broadest face of the cell, thus cutting off similar threads which then expand by taking in water as they differentiate into tracheids. Since the cambial cells are long, pointed threads, they expand into long tracheids with comparatively pointed ends, and as the differentiation proceeds with great rapidity and regularity, all elements cut off from the cambium at the same time expanding at about the same time and to about the same extent, the result is a very regular wood in which, apart from the rays, the main elements are the long, pitted tracheids.

In the hardwood the cambium cells are usually much shorter than in the softwoods, and have not such pointed ends. The cells cut off from them by tangential divisions have end-walls which are comparatively transverse. The cambium cells of the hardwood remain very similar throughout the life of the tree, whilst in the softwoods the fusiform initials increase considerably in length during the first few years. When cells with such comparatively transverse walls, as in the majority of hardwoods, expand whilst the walls are still plastic, the transverse walls are naturally put under exceptional strain, and this may account for the perforation of these walls and the formation of the vessel in this group of trees. The few Dicotyledons in which the cambium initials are reported to be very long are the only Dicotyledons in which the wood is reported to be without vessels. The rupture of the transverse walls in a series of cells lying vertically beneath one another probably removes some of the resistance to expansion. In any case the expansion volume in the vessel segments is much greater than in the softwood tracheid, with the result that whilst the volume of a long softwood cambium initial is usually greater than that of a short hardwood initial, the volume of a vessel segment in a hardwood is usually as large, or larger, than that of a softwood tracheid.

Expansion volume of the successive cells which go to form a vessel is always the expansion of cells which lie almost vertically beneath one another, the upper one evidently expanding first in view of the basipetal sequence maintained by the whole process. It would seem that the expansion of the upper cell accelerates the process of expansion in the adjacent cell below, so that such a tendency to vacuolation spreads downwards more rapidly through such vertical files of cells, whilst those around them are still in a plastic meristematic state. The expansion of the vessels compresses these surrounding cells, which become much longer than the cambium cells from which they were cut off, and when they subsequently thicken their walls and lose their contents, they become fibres. Other cells, which are less compressed, may vacuolate and expand to some extent later and become tracheids. We thus begin to see that the diversi-

fied structure of the hardwood with its vessels, fibres, wood parenchyma, &c., is the natural outcome of the mode of growth and differentiation undergone by a tissue, which has arisen from a cambium with relatively short initials, in which as a consequence many of the original end-walls were relatively transverse.

SOME PRACTICAL APPLICATIONS

This standpoint will need closer examination before it can be applied to many of the problems that primarily interest the forester, but one point may be mentioned here. Evidently spiral grain in the softwoods, with the rapid renewal of basipetal growth in a sheet of very long cambium initials, will be a different thing from the 'undulating' grain often found in the hardwoods, in which the renewal of radial growth spreads downwards more slowly through the system of shorter initials. This problem can be re-examined very profitably from this new angle. Similarly, a whole series of cultural practices in horticulture and forestry should yield results of value when studied by the strip method. For example, this method permits a ready comparison of the renewal of radial growth in stock and scion on either side of a graft union, whilst in favourable cases strips have been obtained right across the region of union. The behaviour of the cambial tissues in the region of the branch crotch can also be studied by this method; in fact, the possibilities it opens up in the examination of radial growth in the tree have not been fully explored as yet. The results of our first year's work in Leeds will be placed on record as soon as possible, and, in the meantime, we shall be very glad to try to supply fuller information to any foresters who wish to give the new method a trial.

A few observations may be made upon the bearing of the results so far obtained on certain more physiological problems which also have practical applications. The observations all point to a resumption of growth activity in the buds in spring. This may be due, as Sachs suggested, to the movement of water into the bud with rise of temperature. During the winter under English conditions the wood gradually fills with water, and in most of our trees, if a branch is placed in warm water, the end having been trimmed smooth, water will be seen to well out of the cut end. This can easily be shown to be due in part to the expansion of the water, and in part to the expansion of the air trapped within the tracheae. In view of the way the wood is now seen to be differentiated, it is evident that when this water movement takes place in the uncut tree, the water must be driven forward ultimately into the tracheal elements which end in the buds. (All the older tracheal files now end at leaf-scars.) The results may well be to start the growth processes into action in the buds, where many living cells were left the previous autumn in a dormant state, though still full of living protoplasm.

When such a bud commences growth, there is every reason to think that the processes leading to the differentiation of new tracheal systems lead also to the formation of new osmotic systems which are capable of drawing water out of the old wood. In the hardwood it is possible to see that the development of

the new vessel systems creates a water deficit in the surface layers of the old wood, because if a cut is made at this stage under a drop of indian ink, the ink is seen to shoot into the freshly opened vessels of the old wood. This is a very instructive experiment, for it suggests at once that the growth of every bud draws water out of the old wood as out of a reservoir, and thus creates a water deficit in the old wood which, as it grows greater, will make it more and more difficult for other buds on the same tree to start into growth. Consequently, buds just beneath a vigorously growing bud may remain dormant, and buds on shaded, lateral branches which tend to be late in starting may never be able to start growth at all, unless the buds already expanding should be killed as in cases of injury by late frost.

As the new wood increases in amount, we find that the first formed, lignified elements of the new increment also inject with ink, whilst the outer and younger elements which are just differentiating are still full of liquid. This is true of both hardwood and softwood, and from this point of view it is most instructive to examine the surface of a 'peeled' softwood in early June. If a very shallow cut is made into the growing tissues, liquid immediately oozes from the cut, but if the cut is made deeper, this liquid disappears instantly into the deeper elements thus cut open, and air also rushes into and between the elements, so that a radiating fringe of white borders the cut into the otherwise cream or orange surface of the growing tissue. If the deeper cut is made under indian ink this enters, forming a black fringe, which extends as far as the average length of the tracheids (usually 1-3 mm.), whilst beyond this again the white fringe shows where air has penetrated between the tracheids.

In a vigorously growing softwood the outer layers of differentiating elements are so turgid with sap that, when the surface is scraped, a fine spray shoots into the air to a height of more than 1 foot. This phenomenon has been observed many times when examining softwoods in June, when all the young tracheids are equally distended with sap. In the hardwoods, although the young vessels are equally full of sap, they have expanded at the expense of the surrounding plastic tissues, and when cut open, although liquid exudes, it does not shoot out with the violence seen in the softwood.

On the other hand, as growth proceeds in the hardwood, and the water in the inner vessels is drawn upon by the differentiation of younger elements outside, the effect of injection with ink is much more striking than in the case of the softwoods. In the ring porous woods in June and July vessels can be injected for many feet by cutting under ink, the ink rushing in at a speed which is often as much as 20 feet a minute, and moving in both directions from the cut for many feet. The outcome of many experiments in this direction is to make it difficult to subscribe to the current view that the vessels should contain liquid under tension when first cut open. In view of the fact that in diffuse porous woods, where the vessels are short, the vessels can be injected in succession, all round the surface of a branch, removed from the tree and devoid of leaves, it seems necessary to conclude that the injected vessels originally contained nothing but water vapour. These observations are

not only of considerable interest in relation to such problems as the ascent of sap, but they also have direct bearing on many practical problems. It is sometimes necessary to kill trees and to prevent regeneration from the roots, as, for example, when trying to clear the vegetation from belts of country to control the movement of the tsetse fly in tropical Africa. In such cases, if a water soluble poison is used so that it will penetrate the occasional cross-walls in the vessel systems, rapid penetration of hardwoods right into the root system is certain, if the wood surface can be cut open under the injecting solution.

The behaviour of ring porous and diffuse timbers, if felled in autumn when a water deficit in the wood may be expected, will also be affected by this behaviour of the vessels. Air will rush into the long vessels of the ring porous type as the trees are felled, and subsequently this will not readily be displaced by liquid water. On the other hand, in the diffuse porous type, a comparatively short distance from the cut surface, all the vessels will still be unopened and many will contain only water vapour; such vessels will rapidly take up water from moisture on the cut surfaces, so that the subsequent behaviour of such timber will be different. Further, these same factors should have direct bearing on the buoyancy of felled timber when floating to the mills.

Of course air can accumulate gradually in closed elements in which the contents fluctuate between water and water vapour, but its accumulation will be slow and the result of release from solution with rising temperature. Heartwood would appear to be the result of such an accumulation of air in closed vessel systems, with its consequent effect upon the permanent water content of the wood, which brings in its train secondary changes in the secretions from the living parenchyma cells. Naturally, therefore, the presence of such heartwood, from which the air will be very difficult to remove, adds greatly to the buoyancy of floating logs. The brief discussion of the balance of water, water vapour, and air in the wood suggests that the movements of water in the tree must be mainly conditioned by the activity of the living tissues. The contrary conclusion arrived at in a recent American investigation (2) has largely been reached by neglect of the simple precaution of preventing access of air when cutting open closed tracheal systems. The control of water movements by the new growth, which commenced in the buds, seems the natural conclusion to draw from the present observations, which are the outcome of the study of the growth processes.

Similarly, it is possible that a re-examination of growth processes in the phloem will show there also a close connexion between growth and food movement. It was found in July this year that when the bark is removed from the tree, a gentle scraping of the inner side of the bark would often provide a very nice preparation of the differentiating phloem. Time has not allowed this suggestion to be followed up so far, but if it is possible to examine the growth and differentiation of phloem in the same simple way, it may be possible to see whether Cockerham's conclusions for sycamore (3) will apply over a wider range of trees. He found that phloem development also took place basipetally in the tree, from the new shoots down over the inner surface of the old phloem.

Some preliminary calculations of the increment of wood and bast added each year to the tree, suggest that if these tissues are thus both formed basipetally, their growth and differentiation from the cambium will account for a considerable amount of the movement of dry matter from the leaves into the older parts of the tree.

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DEFOLIATION OF LARCH AS A CAUSE OF DISEASE

BY W. R. DAY

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INTRODUCTION

IN an earlier paper (1) it has been shown that frost is at least one of the important causes of canker in European larch (*Larix decidua* Mill). In the present article an attempt is made to show that another important cause of disease in larch is defoliation. This may take place in various ways, but in the locality studied, Bagley Wood, near Oxford, frost and birds have been the principal causes. Canker is so obvious a form of injury and so easily seen that it is probable that far too much weight has been given to it in the past as a cause of the ill-thriving of larch plantations. Its economic importance as the chief factor in lowering the value of larch timber has probably helped to accentuate this, because attention tends to be drawn to the immediate and obvious cause of the loss of quality. No larch, however, which grows in a place where frosts occur of sufficient severity to cause canker, ever escapes with this injury alone; it also suffers in other important ways: death of twigs, death of dwarf shoots as a whole or of the growing-point only (i.e. the bud or the tip of the developing shoot), and death of needles. These forms of damage are given in the order of severity of frost required to cause them. The most important damage resulting from them is that more or less extensive defoliation takes place, which if repeated for several years in succession may have very serious results indeed. The defoliation itself falls into two classes. In the one class there is temporary defoliation caused by the destruction of the leaves only, while in the second there is permanent defoliation caused by the killing of the whole twigs, dwarf shoots only, or only the growing-point of the dwarf shoot. This second class of defoliation, if sufficiently extensive, is important since new shoot growth must be made before the tree can be re-equipped with leaves. The exception to this is when the growing-point only of a dwarf shoot dies: this may be replaced by the development of one or more buds at the base of the shoots. In this way multiple dwarf shoots arise (Fig. 2), usually consisting of groups of two or three but sometimes six or even more dwarf shoots all growing from the stem of the original one, the growing-point of which was destroyed.

AGENTS WHICH CAUSE DEFOLIATION

The chief agencies causing defoliation of the larch in Bagley Wood are: *Meria laricis* Vuill., a fungus affecting young trees but rarely serious except in the nursery; *Coleophora laricella* Zll., the leaf-mining moth, which appears to destroy an appreciable amount of the foliage, although apparently not to such an extent as to cause the trees any irreparable damage; *Argyresthia leavigatella*

H. Sch., the larch-shoot moth which bores in the bark of twigs, causes their death, and can in this way do a very serious amount of damage; birds picking out the large buds of the dwarf shoots; and finally, frost. Of these, birds and frost are in limited localities by far the most serious. The liability to frost damage is greatest during early life while the height of the trees is not more than about 12 or 15 feet, and it is during this period that *A. laevigatella* is also most destructive.

Birds are of much more importance than this moth in the locality studied. The picking out of the large buds of dwarf shoots is a well-recognized form of damage to larch;¹ finches, and especially chaffinches, have been mentioned as its cause. In Bagley Wood it has been especially severe during the winter and early spring of 1932, the dwarf shoots of some trees being almost entirely disbudded. The European larch has been the chief sufferer. The Japanese larch (*L. Kaempferi* Sarg.) has been affected to a much smaller extent, while the Dahurian larch, *L. Gmelini* (Rupr.) Gordon and its varieties do not appear to be affected. This type of damage has been noted on European larch in the Forest of Dean and in Denbighshire, and it probably occurs generally and in most if not all years. The buds do not seem to be picked until they have started to swell, and the severe damage done in 1932 may have been associated with the extremely mild weather experienced during the first part of the winter. This so much encouraged early development that in Bagley Wood European larch buds were appreciably swollen in January, and were being picked extensively. The Japanese larch (*L. Kaempferi* Sarg.) were a week or fortnight later than the European. They escaped damage for this time longer and never suffered severely. Little time was available to watch for birds causing this damage and none were actually observed doing it. Hedge-sparrows have been persistently associated with disbudded European larch in Bagley Wood and were also observed on similar trees in Denbighshire. It seems to be quite probable that they are among the species doing this type of damage.

There is no doubt that a certain amount of disbudding has taken place throughout the whole period to which the observations here recorded refer. As no record has been kept in the past of the extent to which this form of damage has occurred, it is impossible to say in what proportion it has been responsible for the death of buds on the branches examined. It is certain that the amount of the damage varies greatly from year to year and from place to place. It is also obvious that this type of damage will be particularly serious when, owing to general defoliation, the development of long shoots has been restricted, and the leaves on the dwarf shoots form a higher proportion of the whole than in a tree that has developed without injury. Thus the more a tree has been defoliated by frost the more serious is the effect of disbudding by birds.

COMPARISON OF THE SPECIES EXAMINED

The importance of frost as a defoliating agent lies in the fact that it not only tends during early life to defoliate the tree as a whole, providing that flushing has already taken place, but that it also kills twigs and shoots. In so far as this

¹ For the determination of the cause of this damage I am indebted to Dr. R. N. Chrystal.

takes place further crops of leaves are prevented. The extent to which defoliation by frost is serious depends on the number of years in succession in which it is repeated and on the proportion of twigs and shoots killed. In this country severe spring frosts occur regularly only in restricted localities. Elsewhere they are only of intermittent occurrence, and it is unusual for severe late spring frosts to occur for two or three years in succession. If this were not so, the successful cultivation of the larch would be considerably restricted in this country. Apart from the frequency and severity of the frosts in any particular locality, the chief factors controlling the seriousness of frost damage are: habit of the species in flushing early or late, its rate of growth, its hardiness at any particular stage and its reaction to frosting, and the suitability of the soil as affecting the general health and rate of growth of the trees. Different species may vary considerably with regard to these characteristics, including the types of soil on which they thrive. The question of soils will not be discussed here, but a comparison of the European larch with some eastern Asiatic species will be made with regard to the other factors. Bagley Wood is a convenient place for making observations with regard to this in that it is liable to suffer from severe frosts, and contains in various stages of growth plantations of the two species of economic importance in this country, European larch and Japanese larch as well as small sample plots of three other larches, the Dahurian larch, *L. Gmelini* *L. Gmelini* var. *japonica* Maximowicz (= *L. kurilensis* Mayr.), and *L. Gmelini* var. *Principis Rupprechtii* Rehd. (= *L. Principis Rupprechtii* Mayr.). *L. Gmelini* occurs in eastern Siberia, the variety *japonica* in Saghalien and the other islands to the north of Japan, and the variety *Principis Rupprechtii* in Korea, Manchuria, and N.W. China. It is unlikely that these trees will ever be of any economic value in Britain owing to their great susceptibility to injury by frost. It is nevertheless of interest to compare these little-known trees with the other more important species.

The Siberian Larches. *L. Gmelini* and its two varieties form a distinct group. They are situated in the higher part of the wood at an altitude of about 350 feet on level ground, but in a situation in which cold air is liable to collect up to a height of about 10 feet. Their chief characteristic is that they regularly flush several weeks earlier than either the European or Japanese larch. They are some of the larches least suited to a winter in which mild weather alternates with frosty periods and is followed by a spring of similar character. *L. Gmelini* and the variety *japonica* seem to be most affected by a climate of this type and may flush again at the beginning of winter during mild weather as in December 1931. On account of this there are very few years in which these larches escape defoliation by frost, and this has resulted in the death of many of the trees. A large proportion of them, however, have grown through the cold lower zone most subject to frosts and may now be expected to survive. The height of twenty trees of each variety counted in a line taken at random comes out as in the table, p. 116. Of this height, growth up to 6 or 8 feet has been made in the last three years, the last two of which have been fairly free from severe frosts. In some instances a height growth of nearly 3 feet has been made in each of the last two

years. This rapid height growth during a comparatively favourable period has probably lifted the tops of many trees out of danger of any further exceptionally severe damage. It will be seen from the following figures that the variety *Principis Rupprechtii* has made the most growth in height, especially considering the age of the trees. All three varieties are, however, now making rapid growth.

<i>Species.</i>	<i>Average height.</i>	<i>Maximum height.</i>	<i>Minimum height.</i>
<i>L. Gmelini</i> (planted 1918)	14 feet	22 feet	9½ feet
<i>L. Gmelini</i> var. <i>japonica</i> (planted 1918)	14 "	23 "	5 "
<i>L. Gmelini</i> var. <i>Principis Rupprechtii</i> (planted 1921)	15½ "	23 "	8 "

In its reaction to frost the variety *Principis Rupprechtii* differs from *L. Gmelini* and the variety *japonica*. The outstanding features of the growth of the two latter larches, in the frost zone where defoliation occurs practically every year, are: the striking lack of cankers, whether on the main stem or branches; the very low number of dwarf shoots killed prematurely; the close dense growth of the branches; and the lack of rapidly growing long shoots (Fig. 1). The dense close growth of the branches is simply caused by defoliation so crippling the tree that no growth of rapidly extending long shoots is possible. Nevertheless there is comparatively little die-back or death of dwarf shoots, and because of this, unless a tree dies through continued defoliation or from attack by root parasites such as *Armillaria mellea*, it eventually grows through the frost zone and begins to make rapid growth. The variety *Principis Rupprechtii* flushes somewhat later than the two larches just discussed. It does not tend to make the dense restricted growth as a result of successive defoliations, but produces a greater number of rapidly growing long shoots. At the same time it is much more subject to canker, and has suffered in this way especially on the main stem. On the side branches the number of cankers is very few. These three larches contrast most strongly with the European larch in the relative scarcity of cankers and of prematurely dead dwarf shoots, although there is a tendency for the growing-point of dwarf shoots to be killed and for multiple dwarf shoots to develop subsequently.

The Japanese Larch. While the above larches stand in rather strong contrast to the European larch they closely resemble the Japanese larch, *L. Kaempferi*, only differing from it phenologically in flushing much earlier and accordingly in being much more liable to defoliation. The Japanese larch flushes very slightly later than the European larch, but quite sufficiently early to be defoliated not infrequently by late frosts. Thus in 1931 both species had developed leaves up to half an inch long by 28 March. It differs from the European larch when growing side by side in frosty localities in that it does not canker so readily either on the main stem or side branches; its dwarf shoots are not so frequently killed, although they very commonly lose their growing-points and so develop multiple shoots; and continued frosting tends to suppress the development of rapidly extended long shoots. On the whole, judging from the plantations in Bagley



FIG. 1.



FIG. 2.



FIG. 3.

FIG. 1. *Larix Gmelini* (Rupr.), Gord. At the top growth is normal; at the bottom abnormal owing to continual defoliation by frost.

FIG. 2. A Japanese larch shoot bearing multiple dwarf shoots.

FIG. 3. On left: the severely frosted Japanese larch branch, no. 5, bearing many multiple dwarf shoots. On right: the slightly frosted Japanese larch branch, no. 4; the older wood bears multiple dwarf shoots.

In middle: one of the European larch branches, no. 3; it bears no multiple dwarf shoots, but except on last year's long shoots, most of the dwarf shoots are dead.

Wood, where the two species grow side by side, on soil which seems to be equally favourable to both, it is decidedly the more resistant tree to frost.

The European Larch. This species is still the most important of the species of the genus in this country. It differs in its reaction to frost from the larches just discussed in its susceptibility to canker both on the main stem and branches (in all species, of course, cankers only arise while the stem is young and before the thick bark of the older stems is formed); in the tendency for its dwarf shoots to be killed as a whole and thus for the tree to suffer permanent defoliation; in the ease with which its small twigs die back, and perhaps particularly in its tendency to continue to produce rapidly growing long shoots in spite of severe successive annual defoliations. On account of its liability to suffer permanent defoliation by the death of twigs and dwarf shoots, it is singularly ill fitted to withstand such successive defoliations, and when they occur it may completely die back as occasionally happens when, for instance, a plantation is so situated as to be exposed to cold easterly winds. It is probable that here is to be found the principal cause of the disasters to European larch plantations reported in the past. The chief advantage that this tree has in a frosty locality is its tendency to grow quickly through it, if not too severely injured, but judging from the Bagley plantations it rarely, if ever, has any advantage in this respect over the Japanese larch, which is to be regarded as decidedly the better tree for planting in such places. It is preferable of course that no larch should ordinarily be planted on such sites.

In 1929 and the few years preceding, severe spring frosts occurred after the above species of larch had come into leaf, and the severity of the damage caused in certain localities made it appear to be worth while to obtain some idea of the amount of injury suffered as a result of defoliation. It was decided to ignore injury resulting merely from the killing of leaves, serious as this may be if it occurs extensively for several years in succession, and to confine attention to permanent defoliation caused by the killing of buds and dwarf shoots, since this is the type of defoliation that can be analysed for some time afterwards.

THE SHOOT SYSTEM OF THE LARCH

In the crown of a larch tree the foliage is born partly by the long shoots developed in the current year and partly by the dwarf shoots. If a larch that is more than one year old is examined in winter, it will be found that the annual shoots can be differentiated for a number of years back and that the buds fall into two classes: the large fat buds on dwarf shoots, and the much smaller buds on the long shoots formed during the previous year. The distinction between the yearly growth of long shoots is made by the marks of the bud-scales of the bud from which each long shoot grew. It is apt to be confused by the development of summer shoots, which results in the formation of two or more rings of bud-scales on the long shoots of one year. Mistakes from this cause, when determining the yearly shoot of growth of a branch, can be avoided by examining the annual rings formed from year to year.

Apart from premature death, three possible fates lie before buds on a newly

developed long shoot of a larch. They may remain dormant, or become dwarf shoots, or develop into long shoots. In the writer's experience few remain dormant, and the exceedingly small number that occurred on the branches that have been examined in connexion with this work have been neglected. The great majority of buds become dwarf shoots, and in a reasonably favourable position have a considerable life in front of them. A dwarf shoot may afterwards develop into a long one, but most do not do so. As on a long shoot, so on a short shoot, a ring of bud-scales is formed each year. These bud-scales persist for some time, and up to a point the age of a dwarf shoot may be told by the number of them. The writer has never attempted to determine the maximum possible age of a dwarf shoot, but it is certainly very much greater than the six years involved in the observations here recorded.

The proportion of the foliage which the short and long shoots respectively bear varies according to the age of the tree, the vigour of its growth, and its freedom from diseases and pests. It would appear that ordinarily the younger the tree the greater is the proportion of foliage on long shoots. When the leaves first appear no long shoots in any stage of development are apparent: all are born in clusters on dwarf shoots. Eventually certain of these elongate and the long shoots appear. This growth of long shoots begins some little time after the dwarf shoots have fully developed their leaves, in the vicinity of Oxford about the end of April with European and Japanese larch, and by the time these shoots are developing most of the danger from spring frosts is over.

THE MEASUREMENT OF DEFOLIATION

The exact determination of the amount of defoliation suffered by a larch tree of any size is not practically possible. The method of measurement adopted here is concerned with the loss of buds or of shoot-growing points. It does not take any account of loss of leaves, and really only gives an indication of the extent to which the tree is deprived of the power of shoot development. It is upon the latter that development of the leaves depends, and therefore indirectly, but of course imperfectly, an estimate is obtained of the loss of foliage suffered. No difference is, however, made between a long and short shoot, since both develop from one bud and each represents one growing-point.

It has been seen above that if a larch branch is examined, the shoot growth from year to year can be determined. On each year's shoot the number of buds or growing-points can be counted, and if a distinction is made between live and dead buds the loss of possible growing-points can be also determined. By careful examination a branch will thus show the shoot growth made from year to year, the number of buds formed, the number developed either as long or short shoots, and the number that died. Here only particular branches from representative trees have been analysed in this way, since it would be much too great a task so to treat the whole of a tree 15 to 20 feet high, such as those from which these branches were taken.

The data obtained in this way are shown in the table on p. 120. This gives the length of each year's shoots in centimetres, the total number of buds,

living and dead, on each year's shoots, and the number of living buds only. Spring frosts of varying severity but sufficient to cause damage occurred from 1926 to 1929. No spring frost sufficiently severe to cause damage occurred in 1930, and none to cause any appreciable damage in 1931. All the figures shown in the table refer to single branches except No. 3, which is the average of eight taken at random from trees that had been badly frosted. No record has hitherto been kept of the severity of the picking of buds by birds, and it is, therefore, impossible to say to what extent the death of buds is owing to this. The mild years 1930 and 1931 give some indication of this, however. The figures in the table for branches Nos. 1, 2, and 3 show that there was an appreciable loss of buds in these years on the European larch branches, which are the only ones much liable to disbudding. It is probable that disbudding is responsible for much, if not for all, of this loss. From the above data also were drawn the curves in the figure on p. 121 showing the proportion of buds living throughout the year in which they flushed. The numbers of the curves refer to the numbers of the branches in the table.

THE EFFECT OF DEFOLIATION AND DISBUDDING

The effect of defoliation upon European larch has been studied by Harper (3) in connexion with the depredations of the larch saw-fly *Nematus erichsoni*, Htg., but no one else ever seems to have paid much attention to this subject. Harper was interested in the growth of the tree and the structure of the wood developing after defoliation. He found that the maximum effect was felt in the year following that in which the tree was defoliated, and was then shown chiefly by a marked reduction in size of the annual ring: in the current year the ring-width was but little reduced, but the autumn wood failed to develop the normal thick-walled cells. The saw-fly defoliates the trees in mid-summer, and a second crop of leaves is developed only towards the end of the summer, which gives the trees very little chance of recovery. A succession of serious defoliations kills them.

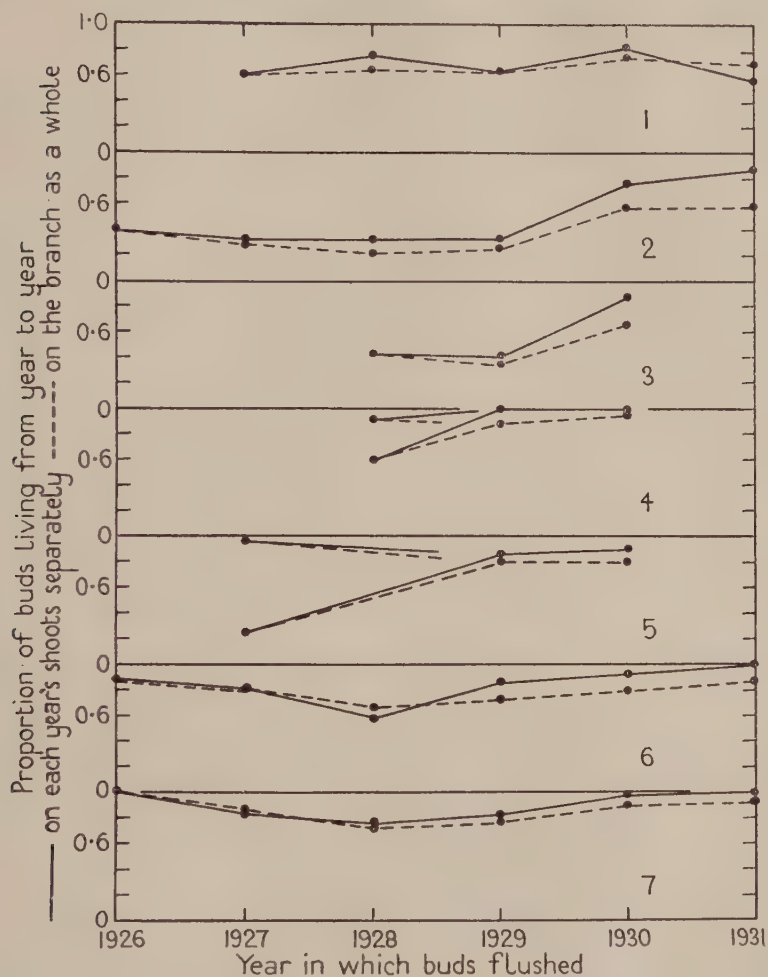
Defoliation by frost may be as serious as that by saw-fly, and a succession of years with severe spring frosts may result in the death of trees or their injury beyond recovery. This, however, is unusual and only takes place exceptionally unless larch happens by mistake to have been planted in an especially unsuitable locality. Ordinarily the number of shoots killed is not enough to prevent a sufficient regeneration of the foliage by a second crop of leaves, and the time of defoliation—usually April or early May at Oxford—is early enough to permit of fairly good recovery. Loss of leaves and of buds or shoots has one effect in common: they both result in poor shoot growth. To a greater or less extent this is shown by all the branches in the poor shoot growth made throughout the years in which severe spring frosts occurred. The actual condition in which a tree is left depends, however, on the manner in which the defoliation takes place, and in this respect the species here discussed fall into two distinct classes. In the one class is *L. decidua* and in the other *L. Kaempferi* and *L. Gmelini* and its varieties.

Details of larch branches analysed

Branch No.	Species of <i>Larix</i> .	Details of Branches.		Year. ¹						Remarks.
				1926	1927	1928	1929	1930	1931	
1	<i>decidua</i>	No. of buds	living + dead	..	54	64	166	404	199	Slightly damaged
			living	..	33	48	106	329	114	
		Length of long shoots (cm.)		..	52	35	121	277	155	
2	<i>decidua</i>	No. of buds	living + dead	38	25	66	112	166	177	Six more of the buds living in 1926 died in 1927
			living	15	8	22	37	128	156	
		Length of long shoots (cm.)		36	12	35	92	116	120	Severely damaged
3	<i>decidua</i>	No. of buds	living + dead	..	..	45	126	271	..	The average of eight severely frosted branches
			living	..	..	21	51	238	..	
		Length of long shoots (cm.)		..	..	32	87	191	..	
4	<i>Kaempferi</i>	No. of buds	living + dead	..	..	38	112*	278	..	Slightly damaged
			living	..	..	23	111*	276	..	
		Length of long shoots (cm.)		..	..	32	52	222	..	
5	<i>Kaempferi</i>	No. of buds	living + dead	..	31	..	340*	10	..	Severely damaged The 1928 buds were indistinguishable from those which flushed in 1929
			living	..	8	..	290*	9	..	
		Length of long shoots (cm.)		..	58	..	112	4	..	
6	<i>Gmelini</i>	No. of buds	living + dead	9	65	50	76	101	231	
			living	8	53	29	65	93	230	
		Length of long shoots (cm.)		9	26	20	34	93	131	
7	<i>Gmelini</i> var. <i>Rupprechtii</i>	No. of buds	living + dead	15	74	29*	108	367	283	
			living	15	63	22*	90	360	279	
		Length of long shoots (cm.)		9	35	2	41	280	154	

¹ The year given is that in which the buds flushed and therefore the year after the long shoots were made and the buds actually formed. Where numbers are marked * much development of multiple dwarf shoots occurred. Damaging frosts occurred from 1926 to 1929, the most severe being in 1927 and 1928. All numbers except 3 are single branches.

The distinguishing character between these classes lies in the liability of the various species to disbudding or loss of shoots whether by birds or frost. Thus the curves show that the European larch branches have consistently suffered the



loss of a considerable proportion of their buds, while on the branches of the remaining species this loss, although not escaped, is consistently very much less. This especially applies to the badly frosted branches. Thus Nos. 2 and 3 (European larch) lost as much as 60-70 per cent. of the buds annually formed, for several years in succession, while the maximum loss suffered by the other branches was 40 per cent. (in 1928 by No. 6, *L. Gmelini*). The consequence of this is that all the eastern Asiatic larches, even though they may have suffered defoliation in successive springs and have made but meagre growth, bear an adequate amount of foliage for their size. The European larch, on the other hand, if badly frosted and especially if it has suffered disbudding by birds as well,

bears comparatively a scanty foliage and may, moreover, suffer severely from die-back of the branch tips, and from canker as well. It has to be remembered, of course, that a frost has only to be sufficiently severe for all the larches here discussed to suffer in this way, but in Bagley Wood at least this has hitherto been a rare and exceptional occurrence, whereas with the European larch it has happened frequently.

In the case of the Japanese larch the ability to escape permanent defoliation depends largely on its capacity to form multiple dwarf shoots. All larches are probably capable of doing this, but in the locality studied it is especially characteristic of this one species. Both the slightly frosted branch (No. 4) and the severely frosted one (No. 5) show how important this phenomenon is in preventing the permanent defoliation of the tree. The curves for these branches have two starting-points. At the lower one the original bud of the multiple shoot is counted as dead, as of course it is, or the multiplication of buds would not have occurred. At the upper one these same buds are counted as alive, as a recognition that the dwarf shoots that bear them are still living, and will develop further buds in replacement. The result is striking, for whereas No. 4 lost four-tenths of the growing-points of its dwarf shoots in 1928, it lost rather less than one-tenth of its shoots completely. Similarly the growing-points of three-quarters of the dwarf shoots on No. 5 were killed in 1927, although only one-twentieth of the complete shoots were lost. On this branch strong multiple shoot development occurred both in 1927 and 1928, with the result that in one case as many as fourteen shoots could be counted around the one original.

As a result of this development a crowded and congested type of shoot formation occurs (Fig. 3). Branches so affected tend to bear no vigorous long shoots unless they are situated near the top of the tree, but they have certain undoubted advantages over the more lengthy and straggling growth, rather scantily clothed with shoots, which is typical of the neighbouring European larches. Firstly, such branches offer very many fewer openings for the entry of a wound parasite, and secondly, and probably much more important, they are much better equipped to carry out photosynthesis; indeed they bear far more shoots per unit of length than would a normal uninjured branch. They thus still remain organs from which vigorous growth can be made as soon as conditions are favourable.

It is not always realized how difficult it is to recognize a tree or part of a tree bearing an abnormally large or small amount of foliage. Graham (2) stresses this, and illustrates it with photographs of a larch (*L. laricina* K. Koch) defoliated to various degrees. These show that only by very careful examination will the loss of one-quarter, or even one-half of the foliage, be observed, and that even the loss of three-quarters might be overlooked without any great difficulty. He defoliated his tree by removing dwarf shoots and therefore in a manner analogous to defoliation in nature by the destruction of the dwarf shoots by birds or frost. The great advantage to *L. Gmelini* and its varieties in escaping any severe permanent defoliation in this manner is obvious, and

indeed this alone makes it possible for them to live for any long period in this country.

In conclusion one may say that the weakness of the European larch as a tree for cultivation in this country lies not only in its susceptibility to canker, but also in its liability to loss of buds and shoots through damage by birds and frost apart from other ways, and thus to partial permanent defoliation. The strength of the Japanese larch and even of the varieties of *L. Gmelini* lies, on the contrary, not only in their greater immunity to canker, but also in the fact that, judging from the locality studied, they very largely escape defoliation in this way. Their recovery from defoliation, which in their case chiefly involves loss of leaves only, is thus very much more rapid and complete than with the European species.

The liability of the European larch in this country to severe defoliation accompanied by the death of many of its shoots does not seem to have been particularly noted. Yet it is a most important characteristic, and its recognition is one of the keys to the successful cultivation of this tree. There are of course many situations where such damage will never be very severe, and many in which it will only occur occasionally; and the probability is that owing to the known susceptibility of the tree to canker the places less favourable for its growth will be avoided, even although its liability to be damaged by frost or to defoliation in other ways is not fully recognized. Nevertheless with the present tendency to extend the cultivation of larch, it is most probable that in the future there will still be trouble from this cause.

SUMMARY.

1. In this paper the importance of defoliating agents such as frost and birds, as causes of disease, is considered in relation to *Larix decidua* Mill., the European larch, *L. Kaempferi* Sarg., the Japanese larch and three other eastern Asiatic larches, viz.—*L. Gmelini* (Rupr.) Gord., *L. Gmelini* var. *japonica* Maximowicz, and *L. Gmelini* var. *Principis Rupprechtii*, Rehd.

2. Defoliation is regarded as temporary when the leaves only are killed, and as permanent when the growing-point of the shoot or one or more whole shoots are killed also. Here temporary defoliation is disregarded, but the amount of permanent defoliation suffered is estimated by counting the number of live and dead dwarf shoots on branches of the trees concerned.

3. It is shown that of the above species in the locality studied *L. decidua* is most liable to severe permanent defoliation owing to complete death or destruction of dwarf shoots. In the other species the tendency is for the shoot either to remain uninjured when the leaves are killed, or to have only its growing-point killed. If the latter happens two or more buds develop in the axil of the scale leaves of the dwarf shoot, thus forming a multiple dwarf shoot. Severely frosted trees of these species tend to produce few rapidly growing long shoots, these being confined chiefly to the upper part of the tree. *L. decidua* on the other hand usually produces few multiple dwarf shoots.

4. *L. Gmelini* and its two varieties differ from the other larches in the habit

of flushing very early. Because of this they are defoliated by frost almost every year, at least while small trees. These trees nevertheless have considerable power of endurance in this climate and may in respect to liability to canker and death of dwarf shoots be regarded as more hardy than *L. decidua*. Figures are given showing the height growth of young trees of all these types in a rather frosty locality.

5. Birds have proved to be very important defoliating agents by disbudding the dwarf shoots. *L. decidua* is the species principally affected, although *L. Kaempferi* is also attacked to a less degree. This form of damage was particularly severe during the early months of 1932 and appeared to be associated with the precocious swelling of the buds induced by the very mild winter.

6. The trees studied in connexion with this work were all about 15 to 20 feet in height in 1931. They lie in Bagley Wood near Oxford, situated in the Thames valley with mainly an easterly aspect. *L. decidua* and *L. Kaempferi* occur here in plantations of some size. The other three larches occur in small sample plots and are included here for comparison with the two economically important species.

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THE DUTCH ELM DISEASE

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INTRODUCTION

SINCE 1928, when the author spent several months examining the distribution of Dutch Elm Disease, a short annual survey has been carried out in September each year, and observations have been made at other times as opportunity permitted. Attention has been largely concentrated on obtaining annual or biennial comparisons of certain definite key areas, and this has of necessity meant that only a very short time each year could be given to the examination of areas not previously visited. Owing to this, information on the distribution of the disease in this country is still somewhat incomplete, though it can be stated with some certainty that the larger areas where the disease is serious are known. In addition to comparative figures illustrating the spread and diminution of the disease, a good deal of information on such aspects of the disease as the type of tree attacked and the means of spread has been collected.

Though a great deal of work has been done on the Continent on the cause, the means of spread, resistant species, methods of control, and other aspects of the disease, no account of this in English has appeared recently. In this paper it is proposed to set out shortly the chief points which emerge from this continental work, and also to give a brief account of the more important aspects of the disease in Britain.

THE DISTRIBUTION OF THE DISEASE

The disease was first described in Holland in 1919, whence the somewhat misleading name of Dutch Elm Disease, and was first recorded in England in 1927; it was probably present on the Continent, and certainly in England before the dates given. It is now widespread in Belgium, Holland, France, and western Germany. It has also been recorded from east Germany (Silesia), Sweden, Denmark, Rumania, Austria, Italy, and Switzerland. Eight cases have been found in Ohio in the United States.

In England the disease is widespread in the south; its status in the different counties is indicated on the map. It is general over the eastern counties, severe local outbreaks being fairly common. In the midland and south-eastern counties the disease is common, but not as frequent as in the east, serious local outbreaks being occasionally met with. Beyond this to the west and north the severity of the disease falls off rapidly; it is known to occur in Devon and on the borders of Wales, and may extend sporadically to the west coast; to the north it has not been recorded beyond York on the east and Chester on the west side of the country. The counties in which the disease has been recorded

are considered in more detail below; the date appended to the name of the county in each case is the year in which the disease was first recorded.

Eastern Counties. Essex (1928) certainly contains some of the worst outbreaks in the country, but the position is not as serious as was at one time supposed. A line survey from the north to the south of the county, carried out in 1932, gave 84 per cent. of the elms as still unattacked. On the other hand, in this county as in Suffolk (1928), where the disease is not quite as severe, it has been found in every area visited. In Norfolk (1928) the disease is definitely more sporadic, though one very serious outbreak near Downham Market is known. The southern non-fenland portion of Cambridgeshire (1928), and Bedfordshire (1928) are both generally infected, though little real damage has been done. In Huntingdon (1931) and northern Cambridgeshire the disease is probably only sporadic. Hertfordshire (1927) shares with Essex the worst outbreak so far discovered, that lying between Bishop's Stortford and Newport; over the rest of the county, and in Middlesex and London (1928), the disease is only sporadic.

South-eastern Counties. In these four counties, Kent (1928), Sussex (1928), Surrey (1928), and Hampshire (1928), the disease appears to be sporadic. The elm is not so general in this area as in the east and midlands, and this may to some extent affect the frequency of the disease. The most serious outbreak covers the north-east and central portions of the Isle of Wight.

South-western Counties. The disease has not been reported from Dorset or Cornwall. In Somerset (1930) it is known to occur in several widely scattered areas, and in Devon (1929) between Exeter and Totnes. In Wiltshire (1929) the disease appears to be generally distributed, and in places, especially near Westbury and Trowbridge, is frequent.

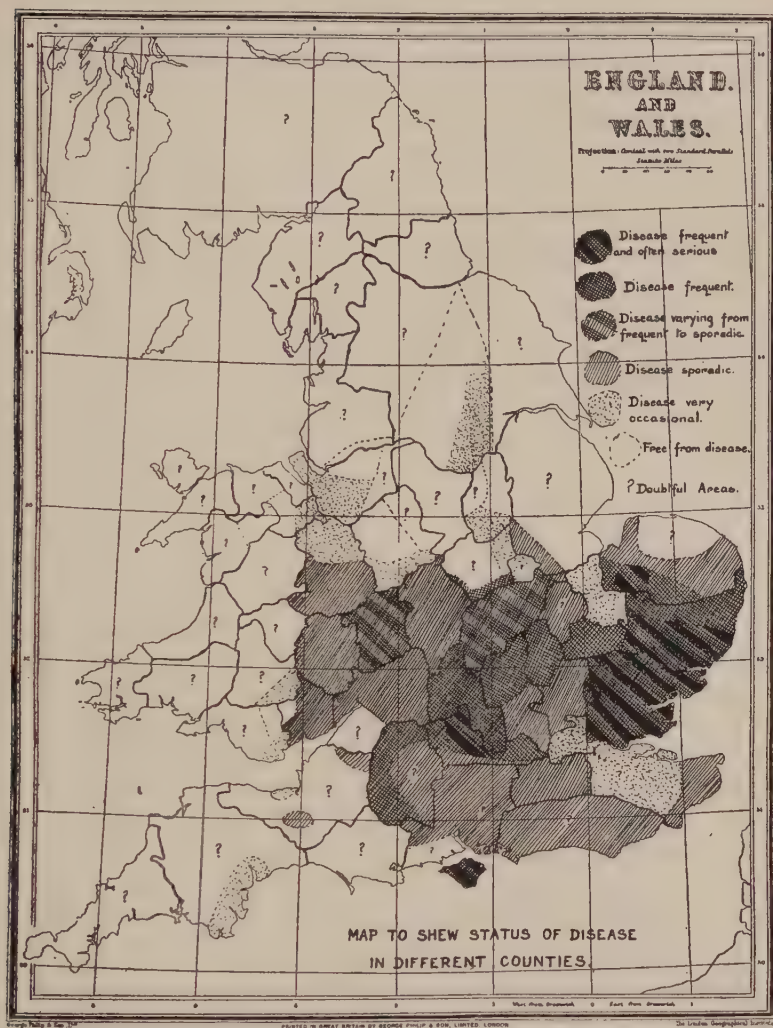
Wales. Only a very small part of Wales has been surveyed, all near the border. The disease is known to exist in Denbigh (1929), Brecon (1932), and Glamorgan (1932). It may well be sporadic over the whole country.

Western Counties. Over Monmouthshire (1931), Herefordshire (1928), Gloucestershire (1929), the southern portion of Shropshire (1928), and Worcestershire (1928), the disease is, as far as is known, sporadic, though in parts of Worcestershire it may be classed as frequent. In northern Shropshire, and Stafford (1928), as far as it has been surveyed, the disease is only occasional.

Midlands. In Berkshire (1928), where the disease is serious near Wantage, Oxfordshire (1929), and Buckinghamshire (1929), with the exception of the Chilterns, the disease is frequent. In Northamptonshire (1928), and the south of Leicestershire (1928), the disease varies from sporadic to frequent, while in Warwick (1928) it is only sporadic. Little is known of north Leicestershire, or of Rutland (1930), but the disease has been seen in both.

Northern Counties. Only comparatively small areas have been surveyed, but the disease is known to occur in south-east Lincolnshire (1931), south Nottinghamshire (1930), south-west Cheshire (1928), and south and central Yorkshire (1930). In none of these areas is it more than occasional. The

remaining northern counties, including Derbyshire and north-west and north-east Yorkshire, have not been surveyed to any real extent, but no reports of the disease have been received from them.



Scotland. No survey has been carried out here, but no record of the disease has been received. Reports of unhealthy elms in one or two areas have been received this year, and it is hoped to investigate them during the coming summer.

The area which it is possible to cover in the time allotted to the survey is of necessity rather limited, and this is reflected by the many areas marked as doubtful on the map. Further work in counties where the survey has been very incomplete might well lead to the discovery of areas where the disease

was either more or less serious than is at present supposed. It will be seen that nearly all the areas supposed to be free from the disease are marked as doubtful on the map. The survey has for various reasons been concentrated largely on areas where the disease was known to exist, and little time has been given to supposedly free areas. But cases have been reported by owners or others from nearly every area where the disease is more than occasional; and this would lead one to infer that it is unlikely to be more than occasional in areas where it has not yet been recorded. Some explanation may be required of the terms used in the notes and on the map: 'frequent' indicates that the disease is generally met with in any area where elms are to be found; 'sporadic' indicates that the disease is widespread, but that many areas can be found where it is absent; the other terms used 'serious' and 'occasional' are self-explanatory.

THE SPREAD AND SEVERITY OF THE DISEASE

In nearly every area visited in 1932 the attack has become less severe since the previous year. Even in areas not visited in 1931, and where therefore comparable figures were not available, trees could be seen which had obviously suffered from the disease in previous years, but which showed no die-back in the current year. Even in the worst areas the attack was definitely less serious than in 1931. In general it may be said to have fallen back to the degree of severity recorded in 1930. Totalling the number of cases in certain areas, which are truly comparable, 1932 shows a decrease of 460 cases on 1931, an increase of 4 cases on 1930, and an increase of 270 cases on 1929.

A large number of figures has been collected, which serve to illustrate the spread of the disease during the period it has been under observation, and its severity in different parts of the country. A number of counts have been made along roads, every elm, other than suckers of bushes, within easy view of the road being counted. These were divided into the following categories: free or 'recoveries' (in 1932, when the number of recoveries was so large, trees which showed certain signs of having had the disease in previous years were often counted separately), diseased, and dead, and expressed as percentages. In cases where the same length of road has been surveyed for two or more years the figures are comparable, but are subject to two sources of inaccuracy. The number of trees counted each year varies somewhat, probably to some extent according to the visibility, and there is always the possibility that dead trees, counted in previous years, may have been removed; this second factor is only likely to be of importance in the worst attacked areas, and if it were to occur on a large scale should be reflected by a large diminution in the number of elms counted.

The counts were all made in September of the year given. The last six localities in the table together make up the line survey from the north to the south of Essex, mentioned above. The only figure of this type for the Continent, which the writer has been able to find, is that given by Van Poeteren (20) for Amsterdam where, in 1929, about 2 per cent. of the elms were reported to have been killed by the disease.

<i>Locality.</i>	<i>Year.</i>	<i>Free and Recoveries.</i>		<i>Dead.</i>	<i>Diseased.</i>	<i>Number counted.</i>	<i>Mileage of road.</i>
		%		%	%		
Newport, Essex . . .	1930	50		10	40	333	4½
" " . . .	1931	33		18	49	389	"
" " . . .	1932	29	19	25	27	307	"
Audley End, Essex . .	1930	84		0	16	94	2½
" " . . .	1931	73		1	26	101	"
" " . . .	1932	74	10	0	16	130	"
Buxted, Sussex . . .	1930	62		11	27	214	¼
" " . . .	1931	51		12	37	208	"
" " . . .	1932	47		21	32	208	"
Stansted, Essex . . .	1931	21		17	62	84	½
" " . . .	1932	31	8	33	28	103	"
Rendlesham, Suffolk .	1931	72		4	24	174	3½
" " . . .	1932	73		9	18	256	"
Sudbury, Suffolk . . .	1932	96	0	0	4	96	4
Halstead, Essex . . .	1932	92	3	1	4	313	9
Braintree, Essex . . .	1932	88	3	2	7	242	5
Chelmsford, Essex . . .	1932	80	5	3	12	254	8½
Witham, Essex . . .	1932	66	14	6	14	157	4½
Maldon, Essex . . .	1932	77	4	6	13	293	7
Wickford, Essex . . .	1932	90	2	1	7	288	5

In other places counts have been made for a number of years—in September unless otherwise stated—of the number of diseased and dead elms in a definite area. Here it has usually been possible to note any dead trees which have been felled, and still to include them in the total. Some of these are set out below, the first figure in each case being the total number of diseased and dead trees, and the figure in brackets the number of these which are dead or felled, if any.

<i>Locality.</i>	<i>1928.</i>	<i>1929.</i>	<i>1930.</i>	<i>1931.</i>	<i>1932.</i>
Bedford	10 (July)	29 (1)	65 (2)	71 (10)	51 (10)
Cambridge	25	12	29 (4)	32 (5)	20 (7)
Totteridge, Herts. . . .	13 (Aug.)	19 (3)	14 (3)	29 (3)	7 (3)
Kennington, Berks. . . .	12	20 (1)	25 (1)	36 (1)	12 (1)
Longstowe, Cambs. . . .	15	30	12	24	22
Buxted, Sussex	51	..	77 (24)	100 (24)	109 (45)
Stansted, Essex	10 (July)	..	43 (16)	98 (40)	60 (50)
Coggenhoe, Northants . .	15 (Aug.)	31	31	..	32 (5)
Kidderminster	6 (Aug.)	6 (1)	15 (6)	..	16 (7)
Between Rugby and Market Harborough	6	17 (1)	82 (1)	..	43 (4)

These figures illustrate the general increase in the severity of the disease from 1928 to 1931, and its diminution in 1932. That there are local exceptions to this is shown at Buxted, where the disease was more severe in 1932 than in 1931, and at Totteridge, Cambridge, and Longstowe, where the usual steady progress of the disease up to 1931 has been interrupted by a year of reduction.

It will be noticed that, despite the decrease in the number of diseased trees between 1931 and 1932, the number or percentage of dead trees has in most cases continued to increase. The severe attack in 1931 has apparently resulted in the death of a number of trees during the late autumn and winter of that year. In addition to the fall in the number of trees showing external signs of the disease, there has been a very distinct reduction in the severity of the disease on many of those trees which are still attacked. There are now relatively far fewer cases of severe die-back than there were in previous years. On the other hand, many of the recoveries have been severely damaged by the disease, and still show the effects by thin foliage and dead branches. This is particularly noticeable in the districts where the disease is most severe.

THE CAUSE AND SYMPTOMS OF THE DISEASE

The disease was at first thought to be due to bacteria, but in 1922 Schwarz isolated the new fungus *Graphium ulmi* from the diseased wood, and described it in detail (19) (a full translation in English of this paper is available (1)). Since then a number of continental workers have carried out successful inoculation experiments with *Graphium* (22), culminating in the work on resistant species which is described later. This fungus has recently been found by Buisman (4) to possess a perfect form *Ceratostomella ulmi* n. sp. It was found that *Graphium ulmi* consisted of two heterothallic groups (+ and — strains), and that growing these together resulted in the production of the perithecial fructifications of *Ceratostomella*. Double inoculations on twigs also have this effect, but so far the *Ceratostomella* form has not been found in nature. The hyphae of *Graphium* occur in the diseased wood, but are hard to find, though the fungus is easily isolated from any piece of wood showing the internal symptoms. This scarcity of mycelium, and the rapidity of the progress of the disease in the tree, would suggest that the fungus may exist in part as a yeast in nature, as it often does in culture. The small isolated yeast bodies would be difficult to observe in sections cut for examination, and could travel rapidly in the tree along the vessels. No real evidence on this point however yet exists.

The symptoms have been described and illustrated in the Forestry Commission Leaflet (2), as well as in a number of other papers, but may be briefly recapitulated here. The first external sign of the disease is a discoloration and withering of the leaves in the crown of the tree or at the ends of the branches; this is usually followed by defoliation. The dead shoots often show a drooping of the tips of the twigs. These symptoms usually appear in July or August in this country, they are seldom observed before the beginning of June, and sometimes do not appear till September. In cross-section diseased twigs or branches usually show one or more rings of brown spots. These occur in the spring wood of the annual rings. In some cases the spots may coalesce to form a more or less continuous circle round the stem. If the bark and a little of the outer wood are removed from an affected stem, longitudinal discontinuous brown streaks of varying length will be observed, these correspond to the ring of spots in cross-section. In severe cases they may extend down into the roots. No case

is known however in which the suckers from diseased trees which have been felled have developed the disease, although in several of the trees the markings in the wood had reached the base of the trunk. The markings disappear very quickly from the wood after death, and dead wood is therefore useless for diagnosis. Occasionally they are not present in all the branches showing external symptoms; this is especially the case with the lower branches of large trees. Several branches on different parts of the tree should be tried before it is assumed that the markings are not present. The total absence of markings is a sure sign that the damage to the tree is due to some cause other than *Graphium ulmi*.

If a large number of cases of the disease are examined, a certain number will be found to show abnormal symptoms both internal and external. The ring of spots in the cross-section is sometimes only a very faint brown, scarcely darker than the normal wood. It is also often incomplete, and sometimes shows only three or four spots, in which condition the symptoms are easily confused with those of the bacterial infection of elms described later. If the spots are few in number, it should be ascertained whether they do in reality form part of a ring, and also in longitudinal section whether they are discontinuous. If they fulfil both these requirements they are likely to indicate the presence of *Graphium*. But in really doubtful cases of this type certain diagnosis can only be procured by culturing the fungus from the wood. Almost any form of browning, yellowing, or wilting of whole or part of the tree has been met with on trees attacked by the disease. But in general the disease starts in one or more branches, usually in the crown, and discoloration and defoliation are general on the branches where they occur. The yellowing of occasional leaves all over the tree, or the yellowing of the leaves over the whole of the tree without any further effect, are not often found in connexion with this disease, and are more likely to indicate damage from flooding, drought, or gas, or some other general pathological condition.

The fungus stimulates the production of tyloses and gum, which block the vessels, and produce the characteristic markings. The action of the disease is said to be due to the interruption of the flow of water by these obstructions, and experiments have been carried out on the Continent which give a good deal of support to this theory (5). But it seems unlikely that the comparatively restricted formation of tyloses and gum could block completely a large stem; and the rapidity with which the disease often acts lends, in the writer's opinion, considerable support to the suggestion that the fungus, or the tree in reaction to it, produces some toxic substance to which the damage in part at any rate is due.

The severity of attack and the rate at which the tree is damaged are very variable. Occasionally large trees may be killed in a single year. More usually the tree will come into leaf again in the spring, and further die-back take place in the summer and autumn. On the other hand, the progress of the disease in the tree is often extremely slow, and trees may show external signs of the disease for several years without any real damage being done.

In the first few years after its discovery the elm disease was attributed by many to the action of adverse climatic factors. Though this view is not now held, climate and soil are still stated to function as predisposing factors. Liese and Butovitsch (13) consider that the primary predisposing cause is to be found in abnormal water conditions around the roots of the tree; Hürländer (12) regards cold and swampy conditions as predisposing factors; while Marchal and Foëx (14) hold that any factor adversely affecting the health of the tree increases its liability to the disease. In this country trees have been found diseased under nearly all possible conditions, in dry sandy soils near Thetford, where the water content must always be low, beside canalized or controlled rivers, where the water-supply is abundant, and the water-level, except for short periods, only varies over a small range, and in parts of the Isle of Wight notably free from frost. The possible good effect of the wet season of 1931 on the health of the elms in 1932, can be put forward as an explanation of the diminution of the disease in the latter year. Though it is not asserted that predisposing factors are never of any importance in connexion with this disease, yet, apart from this one possible instance, the author has found no evidence whatsoever that the disease is affected by climatic or edaphic factors.

THE MEANS OF INFECTION

The method by which the disease was spread remained for a long time obscure. Wind, birds, and insects were all cited as possible carriers, without any real evidence being available. The fungus fructifies on dead wood, but only in sheltered positions such as cracks between wood and bark, and in this country at any rate fructifications are not commonly seen. They also occur in the breeding galleries of the Large Elm Bark-beetle *Scolytus destructor* Ol., and in 1929 Betrem (3) isolated *Graphium* from the intestines as well as the surface of beetles collected from infected trees, and these insects are now accepted as being one of the chief agents of dissemination. The habits of the beetle have been described by Fisher (7) and Fransen (8). The breeding galleries are formed in the trunk or larger branches of the tree. After emergence from the pupal stage and prior to egg laying, the beetles feed for a few days on the young twigs of elms, cutting small channels in the bark usually in the fork of two twigs, but seldom doing any material damage to the tree. For this summer feeding they probably have a preference for healthy trees, but the breeding galleries are only made in trees weakened by some other cause, such as drought, gas, root damage, or Dutch Elm Disease. Thus beetles which have emerged from infected elms tend to carry the disease to healthy ones in the course of their summer feeding. Little work appears to have been done as yet on artificial inoculation with infected beetles, but Fransen (8) has procured one successful result. Most of the observations on the connexion between the disease and the elm bark-beetles have referred to *Scolytus destructor*, the Large Elm Bark-beetle; it is probable that *S. multistriatus* Marsh, the Small Elm Bark-beetle, which tends to attack the branches rather than the trunk, plays the same role, though, since it is much less common, it is almost certainly of less importance.

About a dozen instances in different parts of the country have been examined by the author in which infection had not spread beyond a localized area, a twig or small branch, and in all these one or more summer feeding channels of the beetle were found, the inner surfaces of which touched the ring of spots in the wood. On none of the twigs could any other obvious means of entry for the fungus be seen. Though this cannot be taken as conclusive evidence that the beetle is the usual method of infection, it does lend considerable support to that view.

The distribution of *Scolytus* beetles in this country is not known with any certainty, but *S. destructor* at any rate is common over the whole of the area in which the Dutch Elm Disease is at present known to exist. North of a line joining the Mersey to the Humber both species are said (18) to become rarer, and to be altogether absent from Scotland. This is supported by information supplied by the Natural History Society of Northumberland, Durham, and Newcastle-upon-Tyne who state that in that area *S. destructor* is uncommon, though slightly less so in south Durham than elsewhere, and that *S. multistriatus* has only once been recorded. It would be rash to lay too much stress on the near coincidence of the northern limits, as far as they are known, of the beetle and the elm disease, but it is certainly a point worthy of further investigation.

There is no reason to suppose that *Scolytus* beetles are the only means of dissemination. On the Continent several instances have been given where the Dutch Elm Disease has been present, and no sign of the beetle has been found (10). The relatively high proportion of pollarded and lopped elms attacked in this country would suggest some method of infection through wounds. Dutch workers (22, 24) have reported the impossibility of getting proper infection by the inoculation of cut surfaces, which suggests some other explanation, such as that the beetles have a preference for the sappy shoots produced on these trees for their summer feeding. Recent experiments (5) have shown that the spores of *Graphium ulmi* will tolerate two months' desiccation without loss of viability, so that, where they were sufficiently freely produced, they could be conveyed to healthy trees by wind. But since wounds or punctures are required for successful inoculation (22), and since the spores are produced in such positions that they can seldom reach the open in large quantities, it seems unlikely that this method of spread can be of great importance.

OTHER DISEASES OF ELMS

Consideration of other diseases of elms will be limited to those having somewhat the same effect on the tree as that produced by *Graphium*, and since few of them are of great importance, and several have not been recorded in this country, they will only be treated briefly.

As was stated in the section on Symptoms, flooding, drought, or other factors affecting the roots of the tree may produce a general yellowing of the foliage, and, if severe, die-back of the branches. An interesting case met with was one where the placing of a large manure heap on about half the root area of a row of elms had apparently resulted in their death. Fumes and wind—

especially the latter—also produce a browning of the margins of the leaves. The leaves of elms attacked by the Dutch Elm Disease always go brown or yellow all over, not at the margins only. But damage due to the causes given above, apart from windfall which hardly comes up for consideration here, and that due to smoke and fumes which is practically confined to certain industrial areas, is seldom serious. The commonest non-living cause of severe damage to elms is illuminating gas. Leakages from gas mains have in several cases been found to be causing die-back and death of elms, and this possibility should always be considered if several contiguous trees in a street planting show die-back. Damage due to gas is naturally not confined to elms, and the die-back of other trees in the vicinity is often of assistance in the diagnosis of damage due to this cause. On elms damaged in this manner the bark tends to die from the base upwards, and the discoloration, die-back, and death of the crown, when these take place, are general, not starting in one or two branches as is the case with Dutch Elm Disease. The markings associated with Dutch Elm Disease are of course not present in trees damaged by an escape of gas.

The most important fungal disease of elms, other than the Dutch Elm Disease, would appear to be that due to *Verticillium*; this has been described by Westerdijk and Buisman (22), and recorded from the United States (15, 17), where it appears to be commoner than the Dutch Elm Disease. In Holland the disease is said to occur only on young trees. The wood shows markings which are in many cases almost impossible to distinguish from those due to *Graphium*, though they tend to be more diffuse and fainter. The external symptoms of the two diseases are the same. They can therefore only be distinguished with certainty by culturing from the diseased wood. A number of large elms in Cambridge which were thought at first to have Dutch Elm Disease were examined by Mr. F. T. Brooks, and yielded a *Verticillium*. No other case has been met with among over a hundred elms cultured, and it is unlikely that it is at all common in this country. For ordinary survey purposes it is impossible to separate it from Dutch Elm Disease.

Die-back of elm twigs due to a *Diaporthe* sp., a more serious die-back attributed to *Nectria cinnabarina*, and a discoloration of the wood due to *Pythium intermedium* have been described by Westerdijk and Buisman (22). The last-mentioned produced canker formation and die-back on inoculated plants, as well as the long dark streaks in the wood, which were found in the original instance. The die-back of a row of elms in Holland has been attributed to *Armillaria mellea* (22). May (16) has described a die-back of elms in America probably due to a *Cephalosporium* sp. The symptoms are said to resemble those due to *Graphium ulmi*, except that the discoloration in the wood is more uniform and diffuse. Another disease of elms in America, also showing brownish streaks in the wood, has been described by Verrall (21), and provisionally attributed to a *Cytospora* sp. Of these fungi only *Armillaria* and *Nectria* have been found by the writer on elms in this country, the former at the base of a dying tree, and the latter round the base of small dying branches in several trees; in neither case was there any evidence that they were the primary cause

of the damage. No records of the other diseases mentioned above in this country are known. A number of wood-rotting *Basidiomycetes* occur on older elms, and may sometimes be the primary cause of die-back. Their conspicuous fructifications often occur on elms which have been killed by some other cause.

Westerdijk and Buisman (22) also describe bacterial discolorations in elm twigs. These are not in reality a disease, since they do no damage to the tree. The bacteria enter through dead or broken twigs, leaf-scars, &c., and form long blackish-brown streaks in the wood. These have no regular arrangement, are usually very limited in number, and, though they may fork, are continuous from the point of origin. They are thus fairly easily distinguishable from the markings due to *Graphium*. They are common in this country, especially on older trees, and, as in Holland, appear to do no damage. They occur in other trees as well as elms.

THE RECOVERY OF DISEASED TREES

Little mention is made of this phenomenon in continental papers on the disease. It is not clear whether this is due to its rare occurrence there, or whether it is considered temporary and therefore of no importance. Grossmann (11) refers to the recovery of young trees; and Wollenweber and Richter (25) state that this recovery, which was never observed in older trees, was not due to any inherent development of immunity, since reinoculation produced the disease again. May (15) records one case from Ohio of an elm showing no external signs of the disease in 1931 other than dead wood, in which only the 1929 ring showed any discoloration.

This last case raises the question of the position of the rings of spots in the wood, and of whether they can be taken as an indication of the year of attack. It is generally held that the spots normally occur in the ring of wood formed in the year of attack, and that if the attack extends over several years there will be a corresponding ring of spots for each year, in some part or parts of the tree. Observations made in this country serve on the whole to support this, though exceptions do undoubtedly occur. In the first place the markings associated with any one year's die-back seldom occur in all parts of the tree. As the disease spreads in the tree the distribution of the markings becomes more general, so that the recently attacked portions will show a ring only in the current year, while the part in which the disease started, if not yet dead, will show the whole series of rings. A number of cases are known in which the markings failed to occur in one or more of the years in which the tree was attacked, though material was taken from parts of the tree where they were certainly to be expected. This is especially the case in a year when the damage done to the tree is only slight. On the other hand, the markings sometimes occur a year after the tree has ceased to show external damage; a tree was examined for instance which showed external damage in 1930, but none in 1931 and 1932, but which had internal markings in the rings of 1930 and 1931, though not in that of 1932. It must be understood that the above exceptions depend on the

examination of only a small number of specimens from any one tree, and that the behaviour of part of the tree might be quite normal. The examination is rendered very uncertain in some cases by the difficulty of distinguishing the annual rings, especially when, owing to the weakening of the tree, they have become small and abnormal. Only the careful examination of the whole of a large number of diseased trees could give any definite information on this subject.

In this country recoveries were first observed in 1929, and have been noted every year since. Until 1932 their number was small in comparison with that of new cases, and they tended to be more frequent in areas where the disease was only slight. In 1932 however they greatly outweighed the number of new cases, and occurred in large numbers even in the worst attacked areas. They can be divided into two types, which can be termed complete and incomplete.

The number of complete recoveries is unfortunately small. In these no traces of the markings in the wood can be found. Since in live wood the spots appear to show indefinitely, it is probable that all the infected wood in these trees has died, and that they are truly free from the disease. This type of recovery has been found on trees of all ages, and though some of them still show dead wood, others show no sign whatsoever of ever having had the disease. It is usually found on trees which were only slightly attacked.

The majority of recoveries, those classed as incomplete, still show the markings in the wood. In 1931 cultures were made from the marked wood of three of these, and all yielded *Graphium*. In 1932 16 incompletely recovered trees were cultured, 13 yielded *Graphium*, 2 failed to do so, and the remaining 1 gave *Graphium* in one twig, but not in the other. Two of these cultures were from trees which had been cultured in 1931; one of them was now negative, the other still positive. The case of the tree which gave both positive and negative results suggests that the fungus may be slowly dying out in some of the recoveries at any rate, because in trees showing external damage the fungus can invariably be cultured from wood showing the typical markings. At least two of the trees cultured have shown no signs of external damage since 1928, both these still yielded *Graphium*. No explanation has been found of this dormancy of the fungus in the tree. A very small number of these incomplete recoveries have, after a year or two without external symptoms, started to show them again. It is not known whether this is due to a recrudescence of activity of the fungus already in the tree, or to reinfection.

The number of recoveries noted in 1932 is so much greater than in previous years, that it is impossible to predict that they will subsequently behave in the same manner, i.e. that only a small proportion will again become actively diseased. Should this, however, prove to be the case, the disease will at any rate have received a very definite check.

THE TYPE OF ELM ATTACKED

In most parts of the country the disease is commonest on established but immature trees, but older elms are often attacked, and the disease has been

found in nurseries. Elm hedges, and taller elm suckers are often attacked, but not in proportion to their abundance. In only one case has the writer found the disease on a sucker less than 4 feet in height. The progress of the die-back can be equally rapid on old and young trees, though most of the cases in which it is making no appreciable progress are older trees. Recoveries however are about equally distributed among trees of all ages attacked.

As has been mentioned above, the disease is commonly found on pollarded and lopped elms. On the Continent the view that park and avenue trees are most liable to attack appears to be very generally held. In this country local habitat does not appear to affect liability to the disease, which is found equally in all situations. Naturally most reports received refer to avenue, park, or garden trees, since only when they are in these situations do owners show much interest in them; but this cannot be taken as evidence that the disease is more prevalent in these places.

SPECIES ATTACKED

A great many inoculation experiments have been carried out in Holland and Germany with the object of discovering resistant varieties. Recently this work has yielded valuable results, and several papers published during the last two years will be briefly examined. Westerdijk, Ledebøer, and Went (24) give the results of a series of tests made in Holland in 1929-30. As a result of these *Ulmus pumila* L., *U. pumila* var. *pinnato-ramosa* Henry, *U. japonica* Sarg., *U. wilsoniana* Schneid., *U. racemosa* Thomas, and *U. procera* Salisb. var. *viminialis* Rehd. remained immune from infection, and some degree of resistance was shown by *U. parvifolia* Jacq., and *U. glabra* Hudson var. *fastigiata* Rehd. Seedlings of *U. foliacea* Gilib. from different sources were found to show considerable differences in susceptibility. Wollenweber and Richter (26) working in Germany reported external symptoms of infection for the first time on the supposedly resistant variety *U. hollandica* Mill. var. *vegeta* Rehd., which had hitherto shown only a slight discoloration of the sapwood. At the same time the supposedly resistant Asiatic species *U. pumila* and *U. pumila pinnato-ramosa* also exhibited the latter symptom. Buisman (5) gives the results of further inoculations carried out at Baarn in Holland. In many cases the number of trees of a variety used was too small for any conclusion to be drawn, but *U. pumila*, *U. pumila pinnato-ramosa*, *U. wilsoniana*, and *U. parvifolia* all showed considerable resistance, though they were not immune. Several other Asiatic species, tried only on a small scale, gave encouraging results. On the other hand, *U. racemosa* and *U. japonica*, earlier thought to be immune, were now found to be very susceptible. *U. glabra fastigiata*, which was only tried on a small scale, still showed considerable resistance, but *U. hollandica vegeta* gave 6 infections out of 17 inoculations, and cannot therefore be considered resistant. Resistant individuals have been found to occur in otherwise susceptible species, this is particularly the case with *U. foliacea*. As a result of these experiments Westerdijk, Buisman, and Doorenbos (23) have made recommendations for the replacement of susceptible species by *U. foliacea* Gilib.

var. *dampieri* Rehd., *U. glabra fastigiata*, *U. hollandica vegeta*, *U. pumila*, *U. wilsoniana*, *U. parvifolia* and resistant strains of *U. foliacea*. In the writer's opinion the results given for *U. hollandica vegeta* do not justify its inclusion in this list, and no evidence seems available to support that of *U. foliacea dampieri*. The planting of resistant strains of *U. foliacea* must of necessity await the propagation of a stock of them. Thus, apart from *U. glabra fastigiata*, there remain the three Asiatic species, to which *U. pumila pinnato-ramosa* might well be added. These species would be well worth a trial in any locality where the disease is epidemic, but it must be realized that they are not wholly immune.

In the experiments considered above all the species of elm commonly planted in this country were found to be susceptible. A small number of identifications of diseased trees growing in this country have included all the common species. None of these, with the possible exception of *U. hollandica vegeta*, can be said, on the evidence available, to be more resistant than any other; several diseased trees of *U. hollandica vegeta* have been found. The disease has also been found on a number of less common species in this country including, *U. glabra* Huds. var. *pendula* Rehd., *U. procera* Salisb. var. *argenteo-variegata* Rehd. (*U. campestris argenteo-variegata*), *U. procera* var. *vanhouttei* Rehd., *U. arbuscula* Wolf., *U. americana* L., and *U. pumila* var. *arborea* Litvin. Several of these were included in the experiments in Holland and were found by Buisman (5) to be susceptible.

Apart from *Ulmus*, *Zelkova serrata* Mak. (*Z. keaki* Mayr.) has been found by inoculation on the Continent to be very susceptible to the disease. Recently Wollenweber and Richter (26) have reported wilting of lime (*Tilia parvifolia*) as a result of inoculation with *Graphium ulmi*, and the penetration of the fungus some distance from the point of inoculation, without any external symptoms, in various other deciduous trees. No evidence has been found however either on the Continent or in this country that the disease exists in nature on trees other than elms. If it does attack other trees, it certainly does not do so with the same severity with which it attacks elms.

THE TREATMENT OF DISEASED ELMS

A disease attacking such large trees is naturally not very amenable to control. Various attempts, all unsuccessful, have been made on the Continent to treat the disease by the injection of chemicals into the tree. Since this has proved useless the only method that can be adopted is felling, or the removal of dead wood from diseased trees as is done against the Silver Leaf Disease of Plum in this country. Measures of this kind have in fact been adopted against the Elm Disease in Germany and Holland. No information on their success is available.

In the first part of the summer of 1928 owners of diseased elms in this country were requested to fell and burn them. Only about 25 per cent. complied with this request; and owing to this inadequate response and to the large number of new outbreaks discovered this policy was abandoned. On the Continent the elm is chiefly of importance as a park or avenue tree, in the same way that the plane is with us, and destructive measures of this kind are more

likely to be successful owing to the public or semi-public ownership of most of the trees. In this country the bulk of the elms, and especially the largest elms, are in private hands, and are in reality almost wild. Most of them have probably arisen from suckers, which have been allowed to grow above the hedge level. Owing to their scattered nature and branched growth they are a doubtful asset to their owner, except as an amenity, and their removal, even when dead, is a task many owners would only undertake under the most severe compulsion. This alone would render a policy of felling and lopping, unless rigidly enforced and associated with compensation, a useless task. In any case the number of recoveries that occur, and the number of trees in which the attack is so slow and so slight as to harm them little, are so great that it would be a very doubtful policy to insist on felling.

There is of course no reason for saving a tree which has been rendered unsightly by the disease, and which is past hope of recovery, and such trees should, if circumstances permit, be felled. An elm may be considered beyond hope of recovery either when more than 75 per cent. of the crown is dead, or when beetle attack, as shown by the 'shot holes' in the bark and the frass coming out of them, has commenced in the trunk. In the latter case if the Elm Disease fails to kill the tree, the beetle will kill it. Trees less severely attacked, and possessing amenity value, should have the dead wood removed, and if necessary the remainder cut back to improve the shape. Cutting back should not be carried out, however, unless it is really necessary, since there is no evidence that it has any effect on the progress of the disease, or the power of the tree to get rid of it, and it may increase the chance of further infection. If the tree is only slightly diseased, or if the disease is confined to one large limb which can be removed without spoiling the tree, it is occasionally possible to eradicate the disease by cutting back beyond the lowest point at which the characteristic markings show in the cross section of the wood. It will be found however in practice that it is seldom possible to do this. The disease is not easily seen in the earliest stages, and by the time the external symptoms have become noticeable the internal markings will probably have spread far down the trunk.

The control of the Elm Bark-beetle is possibly not quite so difficult as that of the Dutch Elm Disease, but, like any attempt at the eradication of the latter, would be of little use unless practised generally. When elms attacked by the Dutch Elm Disease are felled, and left lying in the open, they should be barked in order to prevent the beetle breeding in them; windfallen elms should be treated in the same manner, as any increase in the beetle population may lead to an increase in the disease. The cost of any chemical treatment of the bark is probably not justified. Fransen (9) and Demorlaine (6) have recommended the treatment of the trunks of elms which are slightly attacked by the beetle with various substances, which it is claimed stop the attack. This method might be used in an effort to save valuable elms attacked by the Dutch Elm Disease, and in which the beetle had only just started to bore, in the hope that, saved from the beetle attack, they might also recover from the elm disease.

Though the outlook is now more hopeful, the planting of elms is still attended

with considerable risk. For the completion of elm avenues, or even for the filling of gaps in them caused by the disease, this risk is probably worth taking. But for new avenues or other plantings, especially in the south-east and midlands, the use of other trees is to be recommended.

CONCLUSION

A disease such as this, which attacks a tree so large and so common, has naturally received, even in this country, more notice than its severity would warrant. It is unfortunate therefore that it is so little amenable to control, and that those who are working on it can do so little, apart from the discovery of resistant varieties, but record its progress. It is hoped at any rate that this paper will show that, though in very limited areas the landscape has been altered for the worse for years to come, in general the disease is not very serious, and any statement that the elm is doomed is absolutely unfounded.

The surveys, on which most of the information with regard to the disease in this country set out above was collected, were carried out on behalf of the Forestry Commission, to whom thanks are due for permission to publish. Thanks are also due to many owners of trees and others who have given information, or granted facilities for the examination of trees, and especially to Dr. J. Burt-Davy for the identification of elms and observations on the distribution of the disease, and to Mr. W. H. Guillebaud and Mr. W. R. Day for advice on the surveys and the observations to be made thereon.

SUMMARY

The Dutch Elm Disease, which is common in northern Europe, and has been found in North America, is most prevalent in this country in the south-east and midlands, and in the former in certain limited localities has done considerable damage; towards the north and west it becomes rapidly less frequent, and in the northern counties and Scotland it has not yet been recorded.

Figures are given to illustrate the spread of the disease up to 1931, and the marked diminution in its severity in 1932.

The cause of the disease, *Graphium ulmi*, and the symptoms are briefly described. There is no evidence in Britain that the disease is affected by climatic or edaphic factors.

The disease is believed to be spread chiefly by Elm Bark-Beetles, though infection by other means may also take place.

Several other diseases of elms, due to living and non-living causes, and producing somewhat the same effect on the tree as the Dutch Elm Disease, are described. The most important of these would appear to be damage due to gas leakage, and a disease caused by the fungus *Verticillium*.

The 'recovery' of diseased elms is discussed. In the majority of these the fungus is still alive, and there is therefore no certainty that they will not again be damaged.

The disease has been found on elms of all ages, but it is commonest on established but immature trees.

All the species of elm commonly grown in this country are susceptible, but work on the Continent has resulted in the discovery of the resistance in some measure of certain Asiatic species.

The impossibility and undesirability of eradication by felling are explained, and a few suggestions made as to the treatment of elms attacked by the disease.

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THE FORM OF THE STEM IN CONIFEROUS TREES

(Continued)¹

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FORM-CLASSES

IN the last article a description was given of the method by which the field data were worked up and the form of each individual tree determined. The next step is to group the individual curves into their appropriate form-classes. In this connexion the first point to be decided is the size of the unit of form-class.

In a preliminary classification which was carried out an attempt was made to group the trees into narrow classes such as are used in the Swedish Form-Class Volume Tables—60.0, 62.5, 65.0, 67.5, 70.0, &c.—but experience showed that these classes were altogether too narrow, particularly for the younger trees which tend to be irregular. It was decided, therefore, to adopt larger units and the trees were therefore grouped according to their curves into the following classes: 55.0, 60.0, 65.0, 70.0, 75.0, &c.

Each tree was placed in its form-class according to the value of the girth quotient *as read from the stem-curve* at the point midway between breast height and the tip of the tree. Any tree, for example, the curve of which at the point representing half the height above breast height had a girth-quotient value lying between 62.5 and 67.5 was placed in form-class 65.0. It should be noted that this classification was not based on the actual girth-quotient figure for the height at 50 per cent. as obtained by direct measurement. Individual points are subject to irregularity, and the form-class must be determined from the general trend as given by a smooth curve drawn through all the points and not from a single point which may prove to be abnormal.

When all the trees had been grouped into form-classes, the girth-quotient values obtained from measurements on the stem were tabulated, and average figures were worked out for each of the nine points of measurement between breast height and the tip. One thus obtained for each species and form-class an average series of values based on actual measurements.

EXCLUSION OF DOUBTFUL MEASUREMENTS.

In general, the girth quotients, when plotted, gave a series of points which fell fairly evenly along a curve, but it occasionally happened that the points were so irregularly displayed that no satisfactory curve could be drawn, and it

¹ The first instalment appeared in *Forestry*, vi, No. 1, pp. 53 to 62.

became necessary to eliminate such trees from the calculation. Trees of this kind were few in number and occurred chiefly in the younger age-classes of European and Japanese larches, the natural irregularity of young stems being aggravated in the former species by the presence of distortions due to the attacks of canker.

Another form of irregularity which necessitated the elimination of individual trees occurred in all species and among trees of all ages. It was sometimes found that while a smooth curve could be drawn through the girth-quotient points up to the 40 per cent. or 50 per cent. height quotient it could not be prolonged beyond these points and kept in touch with the remaining quotients which generally formed another even series running to the tip of the tree. That is to say, there was a break or 'fault' in the curve, the lower half belonging to one form-class and the upper half to another and generally lower form-class. This irregularity is probably due in most cases to the forking of the stem at an earlier date, as this would lead to a sudden contraction in the values of the girth quotients above the point at which the fork commenced.

The third irregularity which led to elimination of trees was the presence of root swelling above the second point of measurement. Root swelling up to breast height occurred on most of the trees which were dealt with, but it also affected a small number of trees of different species at the 10 per cent. height quotient, while in Sitka spruce its influence could be traced up to the 20 per cent. height quotient on some of the older trees. The effect in such instances of the elimination of the root swelling at breast height was to inflate these values still further, and consequently it was decided to eliminate from the calculation all trees in which the root swelling extended as far up the stem as the second point of measurement (10 per cent.).

THE FORM OF THE STEM UNDER BARK.

This section will deal with the normal form of the stem, under bark, in each of the species investigated. The data for the species which are best represented have been collected from measurements taken in all parts of Great Britain, and they cover a wide range of conditions.

The numbers of trees given in the following sections may differ from those given in the first article, these differences being due in the first place to the fact that certain trees have had to be excluded, and secondly to the collection of additional information.

Norway Spruce (*Picea Abies* Karst). The final investigation of this species has been based on the examination of 422 trees representing all ages up to 57 years. The largest sizes of spruce are not included, as it was impossible to obtain measurements, but there is an adequate representation of small and medium-sized material.

Root swelling as far as breast height was found to be present to an appreciable degree in almost every tree, and after its elimination the series shown in Table I were obtained for the different form-classes:

TABLE I. *Norway Spruce.*

Form-class.	No. of trees.	Girth as a percentage of breast-height girth at per cent. of the stem above breast height.								
		10	20	30	40	50	60	70	80	90
55	2	93.2	85.3	76.4	66.5	56.1	48.1	36.7	24.1	10.6
60	9	95.0	88.1	81.1	71.6	61.1	49.2	38.3	26.3	13.8
65	50	95.1	88.7	81.3	73.7	65.3	55.4	44.1	30.4	15.5
70	168	95.8	90.6	84.7	77.9	70.0	60.5	49.6	36.0	19.0
75	136	96.5	92.0	87.1	81.6	74.7	65.6	54.2	40.3	20.4
80	52	97.1	94.2	90.8	86.1	79.8	71.0	59.2	43.8	22.0
85	5	98.2	96.6	93.7	89.5	83.4	74.5	63.4	47.5	25.9

The bulk of the data for Norway spruce is thus concentrated in four form-classes, viz. 65, 70, 75, and 80; the other classes, 55, 60, and 85, are each represented by a few trees only, and as little reliance can be placed on averages obtained from such scanty data, consideration will be given only to the four principal classes.

The averages have been compared with the theoretical values given by (1) the Höjer-Jonson curves, (2) the Höjer-Jonson curves for Scots pine, and (3) Behre's curves, and the following table shows the amounts by which our Norway spruce percentages differ from those read from the theoretical curves:

TABLE II. *Norway Spruce.*

Form-class.	Theoretical curve.	Difference between actual and theoretical values at percentage heights.								
		10	20	30	40	50	60	70	80	90
65	Höjer-Jonson	+0.9	+0.9	+0.4	+0.3	+0.3	-0.2	-0.9	-2.3	-2.5
	„ (S. pine)	+0.8	+0.7	+0.2	+0.2	+0.3	..	-0.2	-0.7	+0.5
	Behre	+0.7	-0.4	+0.1	+0.1	+0.3	+0.1	-0.2	-1.3	-1.6
70	Höjer-Jonson	+0.6	+0.7	+0.7	+0.4	..	-0.9	-1.7	-2.8	-3.7
	„ (S. pine)	+0.5	+0.6	+0.6	+0.4	..	-0.6	-1.0	-1.2	-0.4
	Behre	+0.3	+0.3	+0.2	+0.1	..	-0.2	-0.4	-0.8	-1.6
75	Höjer-Jonson	+0.4	+0.3	+0.2	+0.2	-0.3	-1.9	-4.0	-6.0	-8.9
	„ (S. pine)	+0.3	+0.1	+0.1	+0.1	-0.3	-1.7	-3.4	-4.5	-5.2
	Behre	+0.1	-0.3	-0.4	-0.2	-0.3	-1.1	-2.1	-2.6	-4.4
80	Höjer-Jonson	+0.2	+0.7	+1.2	+1.0	-0.2	-2.7	-6.6	-11.4	-16.7
	„ (S. pine)	+0.1	+0.6	+1.1	+0.9	-0.2	+2.6	-6.2	-10.1	-12.7
	Behre	-0.2	+0.1	+0.5	+0.4	-0.2	-1.7	-4.0	-6.2	-8.8

These differences are interesting. In all form-classes, our data for Norway spruce when compared with the theoretical curves show an excess in the lower half of the stem, and this excess is greatest in the lowest form-class (65.0), and decreases through class 70.0 to form-class 75.0, after which it again increases. In the upper half of the stem, however, the position is reversed, the differences being constantly negative, while they are smallest in the lowest form-class, increasing up to form-class 80.0.

Of the three curves, Behre's appears to give the best fit, but for form-class

75.0 Jonson's curve for Scots pine agrees very closely with our curve for Norway spruce in the lower part of the stem.

The differences between the data given here for Norway spruce in form-

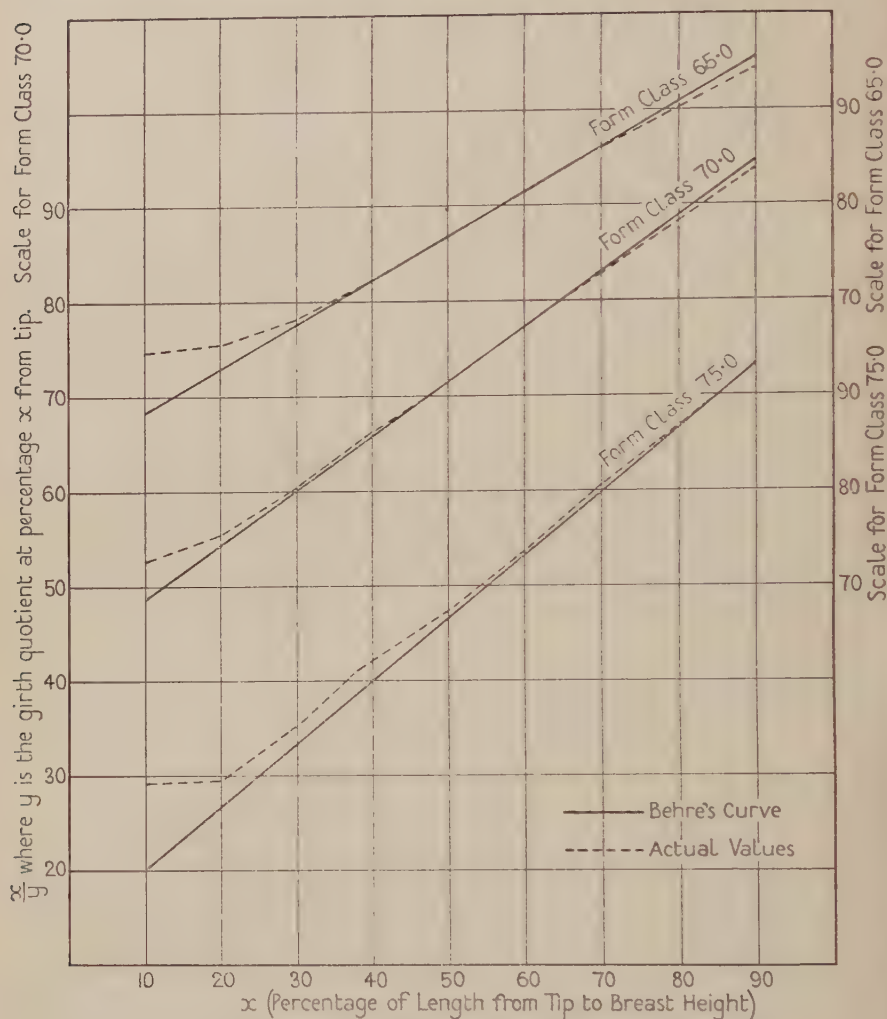


FIG. 1. To show the conformity of Norway spruce to Behre's curves.

classes 65.0, 70.0, and 75.0 and the theoretical values obtained from Behre's equation are shown graphically in Fig. 1, in which we have employed Behre's method of testing conformity to his equation by plotting $\frac{x}{y}$ on x . The agreement is seen to be moderately satisfactory, the only marked divergence from the theoretical values occurring in the sections next the tip.

During the investigation, the data were separated into two groups, a group containing the data from trees of more than 50 years old, and a group containing

the figures collected from trees of less than 40 years of age. It had been observed in the course of the work that the younger trees showed a greater tendency to fall away from the theoretical values in the upper parts of the stem, and this is confirmed by the following figures which relate to form-classes 70·0 and 75·0. These classes are chosen for illustration because they contain between them nearly three-quarters of the material.

TABLE III. *Norway Spruce.*

Form- class.	Age.	Girth as a percentage of breast-height girth at									
		10	20	30	40	50	60	70	80	90	
		per cent. of the stem above breast height.									
70	Under 40	96·0	90·8	85·0	78·1	69·5	59·5	47·9	33·7	18·4	
	Over 50	95·8	90·5	84·5	77·7	70·4	61·2	50·8	37·7	19·5	
	Behre's values	95·5	90·3	84·5	77·8	70·0	60·9	50·0	36·8	20·6	
75	Under 40	96·7	92·4	87·6	81·8	74·0	63·9	50·8	36·2	19·5	
	Over 50	96·3	91·8	86·8	81·5	75·1	66·3	55·7	42·0	21·0	
	Behre's values	96·4	92·3	87·5	81·8	75·0	66·7	56·3	42·9	25·0	

These figures show that when compared with the theoretical values the younger trees give positive differences in the lower half of the stem and markedly negative differences in the upper half. In the more mature material, on the other hand, in form-class 70·0, the differences in the lower part of the stem are only slightly positive, while in form-class 75·0 they are actually negative; in the upper portion of the stem there is a fairly good agreement throughout, except at the last point of measurement in form-class 75·0.

Sitka Spruce (*Picea sitchensis* Carr.). The investigation of this species was based finally on 233 trees, of which more than half were measured in one plantation at Durris, Kincardineshire, which was being felled at the age of 48 years. The rest of the material was obtained from the measurement of sample trees in permanent plots in different parts of the country, and it refers to trees which were much younger, the ages running from 16 to 30 years. One or two trees were obtained, however, in a 60-year-old plot at Benmore, Argyll.

Root swelling was found to affect the data from almost every tree, and in several cases its influence extended to a considerable height. As has already

TABLE IV. *Sitka Spruce.*

Form-class.	No. of trees.	Girth as a percentage of breast-height girth at								
		10	20	30	40	50	60	70	80	90
		per cent. of the stem above breast height.								
55	2	91·3	82·2	72·6	64·2	55·8	45·3	36·2	23·7	13·5
60	16	94·0	86·1	78·8	70·1	60·7	49·5	37·8	24·8	13·3
65	58	94·8	88·5	82·1	74·1	65·4	55·5	43·5	30·1	14·7
70	88	95·8	90·5	84·7	77·9	70·3	61·1	48·7	33·8	16·4
75	64	96·4	91·8	87·4	81·5	74·8	65·0	53·1	37·8	19·2
80	4	97·8	95·0	91·7	87·3	79·8	70·5	55·8	41·5	21·3
85	1	98·2	95·8	94·3	90·5	84·3	76·7	65·2	50·6	28·3

been mentioned, the trees in which the root swelling influenced the measurements above breast height were excluded from the calculations.

The data for the Sitka spruce proved to be rather more irregular than those for the Norway spruce, and the girth quotients for individual trees did not fall so well into line. There was rarely any difficulty, however, in drawing the stem curves, because the tendency in almost all cases was quite definite. The preceding table gives the values obtained for the different form-classes.

As for Norway spruce, Behre's curves give a better fit than Jonson's, but it is again remarkable how closely the data for form-class 75.0 approximate to those given by Jonson's formula for Scots pine.

The differences between the values given above and Behre's theoretical values are shown in the following table for form-classes 60.0 to 75.0:

TABLE V. *Sitka Spruce.*

Form-class.	Difference between actual and theoretical value at percentage heights.								
	10	20	30	40	50	60	70	80	90
60	+0.9	+0.4	+0.9	+0.9	+0.7	-0.5	-1.3	-2.4	-1.0
65	+0.4	+0.4	+0.9	+0.5	+0.4	+0.2	-0.8	-1.6	-2.4
70	+0.3	+0.2	+0.2	+0.1	+0.3	+0.3	-1.3	-3.0	-4.2
75	..	-0.5	-0.1	-0.3	-0.2	-1.7	-3.2	-1.4	-5.8

The general tendency is the same as for Norway spruce, the lower part of the stem agreeing well with the theoretical values, while the upper part shows the same negative differences. These differences are slightly greater than the corresponding differences for Norway spruce, and they show that the upper part of the stem in Sitka spruce tapers, in general, more rapidly than that of the European species.

An attempt was made to separate the data from the middle-aged stand at Durris from the data collected from young trees, but it was found when averages were prepared that there was no significant difference between the two lots of trees.

European Larch (*Larix decidua* Mill). For European larch the data that were used were collected from 435 trees of which almost 200 were 80 years of age and over, and were therefore mature. This species is, therefore, really much better represented than either Norway spruce or Sitka spruce, in which data from mature trees were lacking.

TABLE VI. *European Larch.*

Form-class.	No. of trees.	Girth as a percentage of breast-height girth at								
		10	20	30	40	50	60	70	80	90
		per cent. of the stem above breast height.								
55	2	93.6	84.1	76.7	68.4	57.5	42.1	31.5	18.1	5.0
60	15	94.8	87.9	79.8	70.8	60.1	49.0	36.6	22.2	10.0
65	120	95.1	88.7	81.9	74.5	65.3	55.3	43.5	29.0	13.2
70	202	95.7	90.1	84.6	77.6	69.9	59.6	48.9	34.4	16.3
75	90	96.4	92.4	87.3	81.6	74.3	65.4	54.0	39.7	19.4
80	6	97.4	94.4	90.8	85.5	79.2	67.5	54.3	39.3	21.3

Measurements of young and middle-aged trees were made in all parts of the country in England, Scotland, and Wales, but the bulk of the measurements of mature timber were carried out in the south-west of England.

Root swelling was present to a greater or less degree on most of the trees, but after the elimination of its influence the series given in Table VI were obtained.

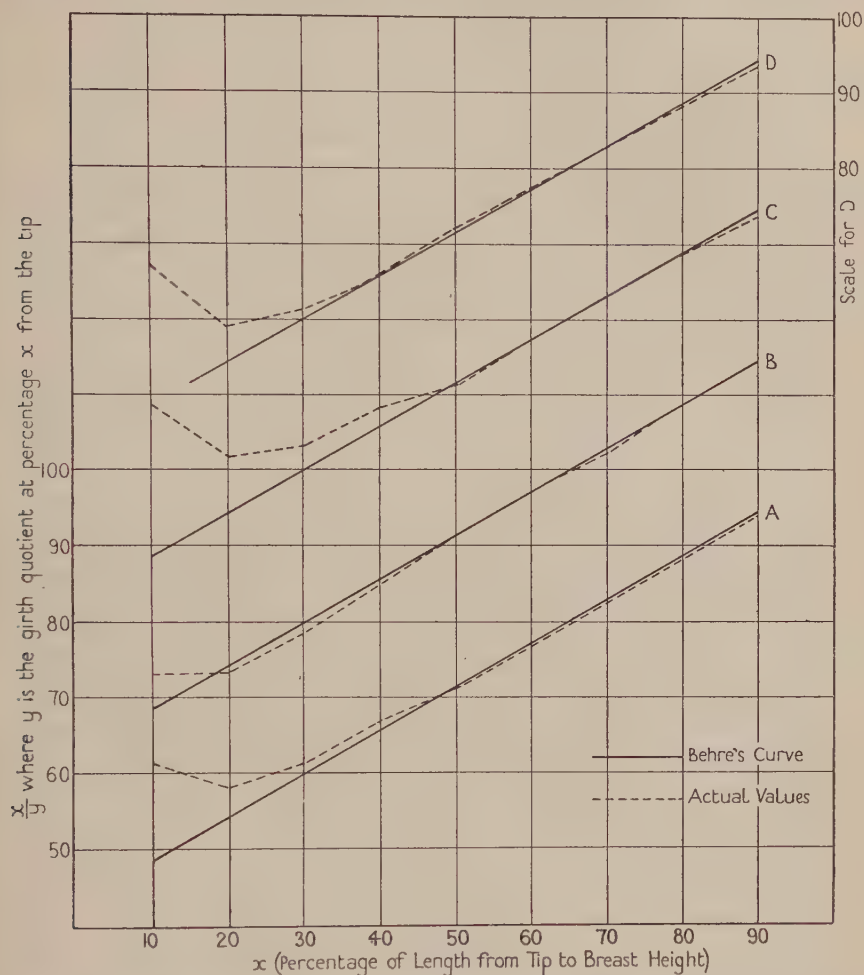


FIG. 2. To show the conformity of European Larch, general data (A), mature trees (B), young trees (C), and of Japanese Larch (D) to Behre's curve for Form-class 70.0.

On comparing the average for form-classes 65.0, 70.0, and 75.0 with the theoretical values for the same classes given by Jonson's curves for Scots pine, and by Behre's general curves, we obtain the differences which are shown in Table VII.

This table shows that the European larch behaves in much the same way as the spruces, for we find in each of the three principal form-classes a slight excess

in the lower part of the stem together with a decrease in the values for the upper part. The differences in the basal half of the stem are of the same order as those which were observed in Norway spruce, but in the upper portion the negative differences in the European larch appear to be greater.

TABLE VII. *European Larch.*

Form-class.	Theoretical curve.	Difference between actual and theoretical values at percentage heights.								
		10	20	30	40	50	60	70	80	90
65	Höjer-Jonson (Scots pine)	+0.8	+0.7	+0.8	+1.0	+0.3	-0.1	-0.8	-2.1	-1.8
	Behre	+0.7	+0.7	+0.7	+0.7	+0.3	..	-0.8	-2.7	-3.9
70	Höjer-Jonson (Scots pine)	+0.4	+0.1	+0.5	+0.1	-0.1	-1.5	-1.7	-2.8	-3.1
	Behre	+0.3	-0.2	+0.1	-0.2	-0.1	-1.3	-1.1	-2.4	-4.3
75	Höjer-Jonson (Scots pine)	+0.2	+0.5	+0.3	+0.1	-0.7	-1.9	-3.6	-5.1	-6.2
	Behre	..	+0.1	-0.2	-0.2	-0.7	-1.3	-2.3	-3.2	-5.4

The data appear to fit both curves reasonably well in the lower part of the stem; Behre's curves give a slightly better fit, but the difference in this respect between them and Jonson's is very slight. The conformity of the data for form-class 70.0 to Behre's curve is illustrated graphically in Fig. 2 (p. 149).

We have seen in the case of Norway spruce how the middle-aged trees had a much fuller form in the upper half of the stems than trees of less than 40 years of age. The information which we possess regarding European larch relates both to old and mature trees and to young trees which are still rapidly growing. In order to determine more accurately how far the form of mature trees differs from that of trees which are still immature, the data were separated into two groups, one of which contained trees of 80 years of age and over and the other, trees of less than 40 years of age. The figures were worked up in the usual way and a series of averages was obtained for each form-class.

Tables VIII and IX show the results expressed as differences from the theoretical curves.

TABLE VIII. *European Larch.*

Form-class.	Age.	Differences between actual and Jonson's values at percentage heights.								
		10	20	30	40	50	60	70	80	90
65	Over 80	+0.7	+0.1	..	-0.6	+0.4	+0.5	+1.8	+1.2	+1.0
	Under 40	+0.8	+0.8	+1.0	+1.3	+0.2	-0.3	-1.3	-2.7	-2.4
70	Over 80	+0.2	..	+0.9	..	-0.1	+0.4	+0.4	+0.1	-0.7
	Under 40	+0.5	+0.2	+0.1	+0.2	-0.1	-2.4	-3.4	-3.9	-4.9
75	Over 80	-0.1	+0.1	..	-0.2	-0.9	-1.2	-3.1	-4.0	-4.6
	Under 40	+0.4	+0.7	+0.5	+0.3	-0.5	-2.3	-3.9	-5.8	-7.2

These tables bring out the remarkable difference in the upper part of the stem between the mature and the young material of European larch. In form-

TABLE IX. *European Larch.*

Form-class.	Age.	Differences between actual and Bebre's values at percentage heights.								
		10	20	30	40	50	60	70	80	90
65	Over 80	+0.6	..	-0.1	-0.7	+0.4	+0.6	+1.8	+0.6	+1.1
	Under 40	+0.7	+0.7	+0.9	+1.2	+0.2	-0.2	-1.3	-3.3	-4.5
70	Over 80	+0.1	-0.3	+0.5	-0.3	-0.1	+0.8	+1.0	+0.5	-1.8
	Under 40	+0.3	-0.1	-0.3	-0.1	-0.1	-2.0	-2.8	-4.5	-6.1
75	Over 80	-0.3	-0.3	-0.5	-0.5	-0.9	-0.6	-1.8	-2.0	-4.0
	Under 40	+0.2	+0.3	..	..	-0.5	-1.7	-2.6	-3.9	-6.6

classes 65.0 and 70.0 the young trees show the characteristic negative differences when their curves are compared with the curves of Jonson and Behre, but the old trees, on the other hand, no longer show this feature. Instead of a deficiency there is, except in the last section of form-class 70.0, a small excess which indicates a satisfactory conformity to the theoretical curves throughout their length. In form-class 75.0 there is the usual deficiency in the upper part of the stem, but this is smaller in the mature trees (Fig. 2).

Japanese Larch (*Larix Kaempferi* Sarg.). This species has not been used extensively in this country until comparatively recent times, and there are still relatively few stands of more than 30 years of age. The data which have been collected form, therefore, a homogeneous mass and give a good idea of the form of this species in its younger stages. They have been obtained from measurements of 182 trees taken in all parts of Great Britain.

The stem in the Japanese larch is exceedingly irregular, and some difficulty was experienced in drawing satisfactory curves in all cases. Root swelling was also present, and it affected the breast-height measurement in about 75 per cent. of the trees.

The form of this species appears to be poorer than that of the European larch for, as may be seen in the following table, the trees fall mainly into form-classes 60.0, 65.0, and 70.0.

TABLE X. *Japanese Larch.*

Form-class.	No. of trees.	Girth as a percentage of breast-height girth at per cent. of the stem above breast height.								
		10	20	30	40	50	60	70	80	90
60	30	94.5	86.9	79.1	70.6	60.1	50.7	39.9	26.3	11.8
65	73	95.1	88.9	81.7	74.2	65.2	55.3	43.8	29.7	13.9
70	78	96.2	90.8	84.4	77.5	69.5	60.8	48.9	33.7	14.9
75	1	96.0	91.6	86.0	80.4	73.7	62.5	51.4	35.7	16.8

On comparing these values with the values given by the theoretical curves one obtains the differences which are shown in Table XI.

The principal point of interest in this table is the marked excess of the values for Japanese larch in the lower part of the stem over the values given by the Höjer-Jonson and the Behre equations. This tendency has been observed in

all the species which have been discussed, but here it is much more pronounced, and again the excess is greatest in the lowest form-class. In the upper part of the stem the Japanese larch is similar in form to the European species; in form-classes 65.0 and 70.0 (Fig. 2) the figures for both species correspond quite well and there is reason to believe that European larch in form-class 60.0 would behave in much the same way as the eastern species.

TABLE XI. *Japanese Larch.*

Form-class.	Theoretical curve.	Differences between actual and theoretical values at percentage height.									
		10	20	30	40	50	60	70	80	90	
60	Höjer-Jonson (Scots pine)	+1.4	+1.2	+1.3	+1.3	+0.1	+0.8	+1.2	+0.3	-0.2	
	Behre	+1.4	+1.2	+1.3	+1.4	+0.1	+0.7	+0.8	-1.0	-2.5	
65	Höjer-Jonson (Scots pine)	+0.8	+0.9	+0.6	+0.7	+0.2	-0.1	-0.5	-1.4	-1.1	
	Behre	+0.7	+0.8	+0.5	+0.6	+0.2	..	-0.5	-2.0	-3.2	
70	Höjer-Jonson (Scots pine)	+0.9	+0.8	+0.3	..	-0.5	-0.3	-1.7	-3.5	-4.5	
	Behre	+0.7	+0.5	-0.1	-0.3	-0.5	-0.1	-1.1	-3.1	-5.7	

Hybrid Larch (Larix eurolepis A. Henry). Ten young trees of this interesting species were measured at Glamis, near Forfar, Scotland. Seven of these fell into form-class 65.0, one into class 60.0, and two into class 70.0.

The averages for form-class 65.0 have been worked out and are as follows:

TABLE XII. *Hybrid Larch.*

Form-class.	No. of trees.	Girth as a percentage of breast-height girth at per cent. of the stem above breast height.								
		10	20	30	40	50	60	70	80	90
65.0	7	96.0	88.9	81.6	75.1	67.1	55.6	41.8	26.4	9.6

The differences between these values and the values given by the two standard curves are as under:

TABLE XIII.

Form-class.	Theoretical curve.	<i>Differences between actual and theoretical values at percentage heights.</i>									
		10	20	30	40	50	60	70	80.	90	
65.0	Höjer-Jonson (Scots pine)	+1.7	+0.9	+0.5	+1.6	+2.1	+0.2	-2.5	-4.7	-5.4	
	Behre	+1.6	+0.8	+0.4	+1.5	+2.1	+0.3	-2.5	-5.3	-7.5	

With such a small number of stems, it has been impossible to obtain a satisfactory average. Nevertheless, it is clear that the values near the tip of the tree are much smaller than normal, while in the lower part of the stem there are present the irregularities that characterize Japanese and immature European larches.

Western American Larch (*Larix occidentalis* Nutt.). Ten trees of this species were measured at Gordon Castle, Scotland, in a plantation 20 years of age. Eight of these trees fell into form-class 60·0, and their average values are given below.

TABLE XIV. *Western American Larch.*

Form-class.	No. of trees.	Girth as a percentage of breast-height girth at percentage of the stem above breast height.								
		10	20	30	40	50	60	70	80	90
60	8	93·1	86·1	77·6	70·0	60·1	49·7	36·9	23·4	11·0

This gives the following set of differences between these figures and the theoretical values.

TABLE XV.

	10	20	30	40	50	60	70	80	90
Höjer-Jonson (Scots pine)	..	+0·4	+0·2	+0·7	+0·1	-0·2	-1·8	-2·6	-1·0
Behre	..	+0·4	-0·2	+0·8	+0·1	-0·3	-2·2	-3·9	-3·3

Except in the last three sections there is a conformity to both curves which for immature trees is remarkable in its closeness.

(To be continued.)

THE FORESTS OF FRANCE ¹

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INTRODUCTION

FRANCE enjoys a wide range of climatic conditions as the result of her geographical position and variation in relief. The west is dominated by oceanic influences; the region round Paris and the north of France are part of the plains and lower hills of continental northern Europe; while the north-east, the Jura, and the Central Plateau belong to the hills and lower mountains, and the Alps and Pyrenees to the high mountains of Europe. To the south, all the French Mediterranean zone is part of the warm-temperate region of southern Europe. These differences of climate, together with important variations of soil, result in a great variety of vegetation, and as was recently shown in the excursions made by the delegates to the Congress of the International Union of Research and Experiment Stations, it is possible to travel for a fortnight and each day to see a completely different type of vegetation.

The principal indigenous forest species are (in order of importance), among broad-leaved species: the oaks (Sessile and Pedunculate), beech, hornbeam, Evergreen oak, Sweet chestnut, ash, the elms, *Acer* species, lime, fruit trees, &c.; and among the conifers: the pines (Maritime, Scots, Aleppo, Austrian, Corsican, Erect Mountain, and Cembran), Silver fir, spruce, and larch. Exotic species have been experimented with for a long period, and much interesting data are available regarding them, but they play a very unimportant part in French forestry.

As regards silvicultural systems, one finds in France coppice, coppice-with-standards, and high forest. The first two systems are generally followed in private and communal forests, and the last in State forests.

BROAD-LEAVED SPECIES

The Oaks. The most important from the forest point of view are: *Quercus sessiliflora* Salib., *Q. pedunculata* Ehrh., *Q. lanuginosa* Thuill., *Q. ilex* L. and *Q. suber* L. One may also mention *Q. tozza* Bosc., abundant in certain coppice growth of the south-west, and *Q. coccifera* L. which in the Mediterranean

¹ Translated from the French by the Editor, in consultation with Mr. R. Bourne.

The Latin names of trees at present current in France have been retained. It has also been thought desirable to retain the metric system; equivalents are given below.

Mètre = 3·28 feet.

Hectare = 2·47 acres.

Mètre cube = 35·1 cubic feet.

Litre = about 1½ pints.

To convert mètres cube (m.c.) par hectare to cubic feet quarter-girth per acre divide by 0·0891.

region constitutes one of the principal underwood elements in the Aleppo pine forests, and persists when the forests are destroyed.

Sessile oak, pure and in mixture with beech and Pedunculate oak, forms magnificent high forest in central and western France: the State forests of Blois (Loir and Cher), Bellême (Orne), Perseigne (Sarthe), Bercé (Sarthe), Tronçais (Allier), &c., are certainly the finest broad-leaved forests in France. They are worked on rotations of 150 to 180 years or more, and the annual yield is fixed in terms of volume. For many decades the majority of these forests have been organized on the principle of allotment to fixed periodic blocks. Actually this principle is being superseded by that of allotment of volume to a single periodic block. These methods of allotment may be summarized as follows: the rotation is divided into equal periods, for example, five periods of thirty years. In the first method, that of fixed periodic blocks, one lays out on the ground an area, theoretically one-fifth of the forest, corresponding to each period, in the hope of being able to maintain indefinitely this allotment. The first block comprises all the woods aged 120 to 150 years, the second 90 to 120 years, the third 60 to 90, and so on. Theoretically, the blocks are self-contained; such a division has been possible in the past because regeneration *à tire et aire*, or on adjoining *coupes*, was followed in France for several centuries under the monarchy. Thus woods of similar age were grouped together. Under the method of a single periodic block the allotment of woods is restricted to the regeneration block which is not of necessity a self-contained block. The composition of the other blocks is only given a titular designation, and often none at all.

In both instances a complete inventory of the regeneration block is made at the beginning of the period, and there is exploited each year as a regeneration felling one-thirtieth of the total volume, plus one-half the increment during the period. The regeneration fellings are marked in a progressive manner: a seedling felling, one or more secondary fellings, and a final felling. The regeneration lasts on an average about fifteen years.

In the other blocks, thinnings on an area basis and of a varying nature are carried out: a thinning from above in order to free the crowns of the final crop trees, taking care not to damage the lower canopy in the immediate neighbourhood, and elsewhere a thinning to remove dominated and dying trees.

In practically the whole of France, with the exception of the south, Sessile oak is also important as standards in coppice-with-standards. Further, in the west, and in some regions of the north, one finds Sessile oak coppice grown for the production of bark for tanning.

Pedunculate oak is found mixed with Sessile oak to some extent everywhere, particularly in the bottoms of valleys. It often fills with Sessile oak an important rôle in coppice-with-standards. In the west, it is common on the banks surrounding fields, and to some extent in the south-west, where it forms interesting forests, especially in the valley of the Adour.

Q. lanuginosa or Pubescent oak is met with chiefly in the south of France, on the hills and lower mountains of Provence, Languedoc, and the calcareous

plateaux of Causses and Périgord. One finds it also on warm aspects in central France, for example, in the neighbourhood of Paris. It is above all a coppice species, rarely showing good development as standards.

Q. ilex is very abundant in the Mediterranean region, and it occurs also in small amount in the Charentes and Causses; it is the type species in the upper Mediterranean zone. It forms coppice worked for the making of charcoal.

Q. suber is found at Rousillon on the spurs of the Pyrenees, in the Maures, and in Estérel. Its eastern variety occurs in the south Landes, in mixture with Maritime pine.

The Beech (Fagus silvatica L.). Beech forms fine high forest in the west, for example, in the State forests of Eawy and Lyons (Seine-Inférieure); in the north in the State forest of Retz (Aisne); in the east in the State forests of Haye (Meurthe-à-Moselle), Darney (Vosges), &c.; and on the southern mountains in the Pyrenean forests of the Montagne Noire (Aude) and elsewhere. In these forests the organization is based on the principle of allotment to a single periodic block with some variations in detail which cannot be entered into here. In the north of France, beech is also important as standards in coppice-with-standards.

The Hornbeam (Carpinus betulus L.). This species is widely distributed in the north and east of France, where it is an important species in coppice. It only plays a subsidiary rôle as standards in coppice-with-standards in the absence of more valuable species such as oak, ash, elm, beech, &c.

The Sweet Chestnut (Castanea sativa Milb.). Sweet chestnut occurs in Alsace, in the west, and in central France as coppice or coppice-with-standards. One of the most interesting is the State forest of Vouvant (Vendée), unfortunately considerably damaged by Ink Disease. The chestnut also forms old, open, high forest, particularly on the central plateau.

The Elms. These species are much used for boundary lines, and play an accessory part as standards in coppice-with-standards. *Ulmus campestris L.* is found particularly on the alluvial soils, for example, in the Rhone valley. *U. montana* With. is distributed on the hills and plateaux of the north-east.

The *Acer* species play a similar part to the elms, while the alders, birches, poplars, limes, and fruit-tree species are of little forest importance.

THE CONIFERS

The Maritime Pine (P. pinaster Soland). The Maritime pine occupies large areas in France. It occurs naturally in the Mediterranean region of Maures and Estérel, and in the Gascony Landes. It has been extensively introduced throughout the west up to the north of the Loire, and in Brittany, but it is in the region of the Landes (Gironde, Landes, and Lot-et-Garonne) that it forms the most important forests.

Following the work of Bremon tier in fixing the dunes, and of Chambrelent in rendering the Landes healthy, Maritime pine stands have been formed on a large scale, and this region is covered with an immense forest extending to 900,000 hectares, of which 800,000 is *P. pinaster*. The State owns a long belt

along the sea, of variable width, and extending to about 46,000 hectares. The remainder is communal and private forests.

Maritime pine is managed for the production of wood (pitwood and sawn-timber) and resin. The total production of the Landes region in a normal year is 3 million cubic metres of wood, and 125 million litres of resin, being 3·8 cubic metres and 150 litres per hectare. The resin is made into turpentine and rosin.

During the past sixty years the Hugues system of resin-tapping has been practised. It consists in the making of an elongated wound on the tree, called *care* or open blaze, and the collection of the resin in a glazed earthenware pot with the help of a zinc lip. The blaze is renewed periodically by means of a shaving as thin as possible; this is called the *pique*. These parings are made, in principle, once a week. The yield, called *amasse*, is collected every five to six weeks. The blaze is treated during four consecutive years; its annual dimensions are as follows:

			m.		m.
First year	.	.	Height 0·60;	average width	0·09
Second year	.	.	" 0·65	" "	0·09
Third year	.	.	" 0·85	" "	0·08
Fourth year	.	.	" 0·90	" "	0·069
Total	.	.	.	3 m.	

Distinctions are made between light tapping (*à vie*) applied to trees as soon as they have attained sufficient dimensions; heavy tapping to death (*à mort*) for four years before the trees are due for felling; and medium tapping (*à l'épuisement*).

The management of the State forests situated on the Bures is on the following general lines. The length of the rotation is generally 72 years, except in the series adjoining the sea, where it is 64 or 56 years. The resin-tapping being practised in periods of four years, the forest is divided into large sections called divisions as follows: $\frac{72}{4} = 18$, $\frac{64}{4} = 16$, $\frac{56}{4} = 14$.

The fellings are regulated in the following manner: during the first period of 4 years, division 1 is tapped *à mort*, it is clear-felled at the end of the fourth year, and natural regeneration begins to come in. Divisions 2, 3, and 4 are progressively tapped *à l'épuisement*, that is more intensely in division 2 than 3, and 3 than 4. In the other divisions tapping *à vie* is done on the dominant trees, that is those with a girth of 1 m. or more at breast height, and a tapping *à mort* on the pines due to come out in thinnings. In the youngest divisions, cleanings in the crop are made from the fourth year (removal of broom and dead trees), then thinnings without tapping. Trees thus to be removed are tapped *à mort* as soon as the trees are large enough, 0 m. 50 girth at breast height.

The Scots Pine (P. silvestris L.). Scots pine is indigenous to the Vosges, the Alps, the Central Plateaux, and the Pyrenees. In each of these regions there are local races: at Haguenau, Wangenbourg (Bas-Rhin), Bruyères (Vosges),

Montgenèvre (Hautes-Alpes), Forez (Loire), Mathe des Angles (Pyrénées-Orientales).

Scots pine has been very largely introduced throughout the whole of France, with the exception of the south-west and the Mediterranean region, and forms important blocks of artificial forest, both private and State. The following five State forests may be mentioned: in Normandy, the forest of Roumare, and Rouvray (Seine-Inférieure); and in central France, Fontainebleau (Seine-et-Marne), Rambouillet (Seine-et-Oise), Orléans (Loiret), &c.

In the State forests the length of the rotation, although very variable, is generally between 70 and 100 years. The yield possibility is fixed, according to the forests, either entirely by area, or by area for the thinnings, and by volume for the regeneration fellings, following a method analogous to the single periodic block system described above. Natural regeneration gives satisfactory results under favourable conditions as at Roumare and Rouvray, but in the majority of instances it is incomplete, and has to be supplemented to a greater or less extent by artificial means.

Varieties of P. laricio (Poir.). The Austrian pine is extensively employed in the reafforestation of calcareous soils, particularly in Champagne, and in eastern France in reafforestation in the Alps. Corsican pine is also an interesting reafforestation species, not sufficiently used in my opinion. There are small plantations of this species throughout France, notably in Sologne, and in reafforestation at Argonal, &c.

The Aleppo Pine (P. halepensis Mill.). The Aleppo pine is localized in the Mediterranean region, where it is characteristic of the lower Mediterranean zone. It occurs pure, or on the fresher sites mixed with Evergreen oak, and forms important blocks which are unfortunately too often devastated by fire. In certain forests it is tapped for resin by the same method as for *P. pinaster*; with somewhat less intensive tapping it produces a little more resin.

The principal Aleppo pine forests are the State forest of Lubéron (Vaucluse), severely affected by successive fires, and the communal forests of Gémenos, Cassis (Bouches-du-Rhône), Ollioules (Var), &c.

For long treated as even-aged high forest on a rotation of about 60 years, the forests of Aleppo pine administered by the State are actually worked on the selection system, principally because of the danger from fire. The exploitable size is generally a girth of 1 m. 20, which corresponds to an age of 60 years; the felling cycle is ten years; and the annual increment is of the order of 1 m.c. 50 per hectare.

Mountain Pine (P. uncinata). This species, known in France as the *pin à crochets*, occurs naturally in the Alps and Pyrenees. It is often used in reafforestation on high mountains. The finest forests are in the eastern Pyrenees. Here it occurs naturally in mixture with Scots pine and Silver fir between 1,200 and 1,500 m., and between 1,600 and 2,100 m. it forms important pure stands over a large area. Outstanding communal forests are Osséja, where there are crops carrying over 500 m.c. per hectare, Matemale and Formiguères, and the State forests of Font-Romeu, and Barrès. In all these forests *Armillaria mellea* has

and is causing severe losses, but the damage has appreciably decreased in recent years.

Cembra Pine (*P. cembra* L.). This species is found in France in the highest forest zone of the Alps. It occurs in isolated groups mixed with the last of the Silver fir and spruce above 1,400 m., and together with larch and Mountain pine is the last representative of forest vegetation surrounded by rhododendrons and dwarf willows at about 2,500 m. Exceptionally, it forms a pure stand over a considerable area on the Ayes plateau in the forest of Villard-St.-Pancrace near Briançon (Hautes-Alpes).

Silver Fir (*Abies alba* Mill.). The Silver fir occurs naturally in France in the Vosges (between 350 and 1,300 m.), Jura, Alps (between 600 and 1,500 m.), the Central Plateau, the Pyrenees, and in a little corner of Normandy. In Normandy it forms only poor stands, but elsewhere it makes magnificent forests, pure or in mixture with beech, or with spruce in certain places in the Jura and the Alps. During the last fifty years it has been introduced outside its natural habitat, particularly in poor coppice-with-standards, and with complete success. Silver fir is, therefore, a valuable species whose natural range has been appreciably extended.

The following are the finest forests: Vosges: those in the region of Gérardmer, Saint-Dié, Remiremont (Vosges), Ribeauvillé (Haut-Rhin); Jura: the State forests of Joux and Levier, and the communal forests of Esserval Tartre (Jura); and Pontarlier (Doubs); Alps: the State forests of Grand Chartreuse (Isère) and Lente (Drôme), and the communal forest of Durbon (Hautes-Alpes); the Central Plateau: the State forests of Chambons, Mazan (Ardèche), and Murat (Cantal); Pyrenees: the State forests of La Plaine, Comefroide-Picaussel, Callong-Mirailles (Aude), and the communal forest of Lazuns (Basses-Pyrénées).

The forests of Silver fir are managed either as even-aged high forest or on the selection system according to the region and the ownership.

In even-aged high forest the principle of allotment to a *quartier bleu* is applied. The compartments are allotted to two groups: the one is called *quartier bleu* because it is generally coloured blue on the maps, and it contains the oldest stands to which regeneration fellings are to be applied; the other group consists of the younger compartments due for thinning.

We will state what is clearly only an approximation, namely that in a forest thinned normally and grown on a long rotation, diameter increment is almost constant, and age and size can be interchanged. Let us suppose that the exploitable size is a diameter of 0 m. 60, which corresponds to an exploitable age of 140 to 150 years, then we will call *vieux bois* old trees which have a diameter of 0 m. 45 and over, that is which have passed two-thirds of the exploitable size, and *bois moyen* those trees 0 m. 20 to 0 m. 40 diameter, that is which are one- to two-thirds of the exploitable size. An inventory is made of all the trees of a diameter of 0 m. 20 and upwards throughout the whole extent of the forest. Let v be the volume of the old trees, and v' the volume of the middle-aged trees at the end of the general inventory. If the forest be normal,

then in order to keep it normal, on the basis of the hypotheses made, it is necessary to realize the total volume of the old trees v during one-third of the rotation; if n be the length of the rotation, the volume to be realized each year among the old trees is $\frac{v}{n/3}$. In order to determine the annual possibility, it is necessary to add to this figure:

- (1) the increment of the old trees $\frac{1}{2}vt$, where t is their annual increment;
- (2) the fraction to be realized annually of the increment of middle-aged trees: $\frac{1}{q}v't'$, t' being their annual increment and $\frac{1}{q}$ the fraction to be realized.

The total annual yield or possibility is then given by the formula

$$P = \frac{v}{n/3} + \frac{1}{2}vt + \frac{1}{q}v't'.$$

Two considerations enable a test of the normality of the forest to be applied:

(1) *The proportion of old and middle-aged trees.* If we take the exploitable age to be 150 years, the old trees are 100 to 150 years, with an average of 125 years. The middle-aged trees are 50 to 100 years, with an average of 75 years. One ought, therefore, to have on the hypothesis stated

$$\frac{v}{v'} = \frac{125}{75} = \frac{5}{3}.$$

That is to say the volume v of the old trees, and v' of the middle-aged trees, ought to be $\frac{5}{3}$ and $\frac{3}{5}$ respectively of the total volume of the inventory. In practice, if the proportion is too far out, a transfer from one category to another can be made to secure a satisfactory equilibrium in exploitation.

(2) *Average volume per hectare.* The average volume per hectare is calculated for the whole forest, and one approximates the figure so obtained to that of the region, for example, 350 m.c. What is to be realized is increased or decreased according to the over- or under-stocking of the forest.

This method, debatable in theory, has given good results in practice. In spite of the apparent rigidity of the formula, it remains very flexible, because the framer of the working plan can adjust at his will the values t , t' , and q in fixing the possibility. The plans are established for an arbitrarily fixed period, generally about twenty years.

The following procedure is followed on the application of the plan. One begins by deducting the windfalls which have taken place since the previous year, then the thinnings are marked, and their volume deducted; what remains of the possibility is used to mark regeneration fellings in the *quartier bleu*.

A large number of Silver fir forests, particularly in the Jura and the Alps, are worked on the selection system. The exploitable size is generally fixed as a diameter of about 0 m. 60. The felling cycle is most frequently 10 years. The yield or possibility is fixed by the same formula as has been stated for the even-aged forests.

A method much employed by certain individuals is that called *du contrôle*. The amount to be exploited in each compartment is based on a comparison of the inventory made in the compartment before each exploitation. The felling cycle is short, for example, 5 years. These comparisons furnish very interesting data.

The production of Silver fir forests varies from 6 to 15 m.c. per hectare per annum according to region and altitude. For the Vosges a figure of 7 to 8 m.c. is a good average, while in the Jura and the Alps considerably higher averages are obtained.

Spruce (*Picea excelsa* Link). The spruce occurs above the Silver fir in the Vosges and Jura from 600 m., and in the Alps from 800 m. altitude. It forms very fine forests, pure and mixed, in the Jura with Silver fir, and in the Alps with Silver fir, larch, and Mountain pine. The best known are the State forests of La Fuvelle, Noirmont, Le Risoux near Pontarlier (Doubs), and La Grande Chartreuse (Isère); and the communal forests of Thônes, St.-Jean-de-Sixt, La Clusaz near Thônes, Chatel, Chamonix (Haute-Savoie), Beaufort, and Bourg-St.-Maurice (Savoie).

The same methods of management are used as for Silver fir, but the selection system is commonest. In the State forests of Silver fir and spruce about one-third are managed on the selection system and two-thirds as even-aged high forest, while three-quarters of the communal forests are selection forests.

Larch (*Larix europaea* D.C.). The larch is natural to the Alps and forms fine stands both pure and in mixture with Silver fir, spruce, and Mountain pine between 1,000 and 2,500 m. It occurs as more or less open high forest shading fine pasture regularly grazed. Among the best-known forests are the communal forests of Meyronnes (Basses-Alpes) and Montgenèvre (Hautes-Alpes).

Throughout the east of France it has been frequently planted even on the plains; these plantations grow vigorously in early life, but should be felled early.

FOREST STATISTICS

The area of French forests is 10,353,000 hectares, which represents 19 per cent. of the total land area. The following table gives a classification of the area according to the nature of the forest and ownership:

<i>Nature of the forest.</i>	<i>State forests.</i>	<i>Communal and other publicly owned forests.</i>	<i>Private forests.</i>	<i>Total.</i>
Unproductive areas (blanks, rocks, &c.)	Hectares. 148,500	Hectares. 76,500	Hectares. 276,300	Hectares. 501,300
Coppice	26,000	272,000	1,993,000	2,291,000
Coppice-with-standards	333,000	1,097,000	2,416,700	3,846,700
Coppice in conversion	104,000	16,200	45,000	165,200
High forest	822,500	715,300	2,011,000	3,548,800
Total	1,434,000	2,177,000	6,742,000	10,353,000

<i>Annual Production.</i>	<i>m.c.</i>	<i>m.c.</i>	<i>m.c.</i>	<i>m.c.</i>
Timber	1,500,000	1,600,000	4,200,000	7,300,000
Firewood	1,800,000	3,900,000	12,800,000	18,500,000
Total	3,300,000	5,500,000	17,000,000	25,800,000

In order to obtain the total wood production of France it is necessary to add the yield from roadside and park trees, small plantations of poplars, &c., which on the aggregate give a not unimportant total, although very difficult to determine accurately.

In round figures one can give the following totals:

Timber	8,000,000 m.c., a figure under consumption.
Firewood	19,000,000 m.c., a figure above consumption.
Total	27,000,000 m.c.

With regard to the relative importance of the different species one can say that broad-leaved species represent more than two-thirds of the total forest area. The proportions of the different species are as follows: broad-leaved, the oaks (Sessile, Pedunculate, and Pubescent) 15 per cent. of the total forest area, beech 15 per cent., hornbeam 8 per cent., Evergreen oak 4 per cent., &c.; and coniferous, Maritime pine 12 per cent., Scots pine 7 per cent., Silver fir 6 per cent., spruce 3 per cent., larch 1 per cent., Aleppo pine 0.5 per cent., &c.

From the point of view of soil, the forests are distributed as to 40 per cent. on calcareous soils and 60 per cent. on non-calcareous soils.

The importance of the different geological strata is approximately as follows:

Primitive rocks, approx. total area in France 20 per cent., of which 13 per cent. is forest.

Primary	"	"	"	8	"	"	16	"	"
Secondary	"	"	"	36	"	"	19	"	"
Tertiary	"	"	"	28	"	"	19	"	"
Quaternary	"	"	"	2	"	"	14	"	"
Recent	"	"	"	6	"	"	6	"	"

The distribution of the forests according to altitude is approximately as follows:

Forests located at	0 to	200 m. altitude	constitute	37 per cent. of total French forest area.
"	"	200 " 400	"	24 " " " "
"	"	400 " 600	"	12 " " " "
"	"	600 " 800	"	7 " " " "
"	"	800 " 1,000	"	10 " " " "
"	"	1,000 " 1,200	"	4 " " " "
"	"	1,200 " 1,400	"	3.5 " " " "
"	"	1,400 and above	"	2.5 " " " "

ADMINISTRATIVE ORGANIZATION

All central forestry matters are in the hands of a special department, Administration des Eaux et Forêts, under the Minister of Agriculture. It is made up as follows:

(1) A central department, the Direction générale des Eaux et Forêts,

established at Paris under the Minister of Agriculture and consisting of a *Directeur Général*, a *Conseil d'Administration*, and *Bureaux de la Direction*.

- (2) Five *inspecteurs généraux* charged by delegation from the Minister to control the field service.
- (3) French territory is divided into forty-three *conservations* each directed by a *conservateur* assisted by a *chef de bureau* and comprising one or more departments (the principal divisions of France).

The *conservations* are divided into large or smaller districts called *inspections* or *chefferies* respectively, placed under *inspecteurs* or exceptionally *inspecteurs-adjoints*. Where the districts are extensive they themselves are divided into *cantonnements* under *gardes généraux* or *inspecteurs-adjoints*.

In a certain number of districts there is, side by side with the ordinary service, a special service under the *inspecteur* and charged with the establishment of working plans. In the same way, in mountainous country there is a special service for torrent control, &c.

The work of the forest officers is very varied. Apart from the large amount of work in connexion with the State forests and communal and other publicly owned forests which are, in principle, under the control of the forestry service in respect of such matters as marking and sale of fellings, road work, reforestation, inspection, and control of offences, the forest officers have an important part to play in matters of public interest: diverse inquiries, supervision of regulations relating to reforestation, supervision of private forests classed protection-forests, supervision of clearances, protection of fish in non-canalized waterways, co-operation in the destruction of harmful animals, regulation of fishing, hunting, &c.

Each inspector has a clerk or chief clerk charged specially with the work of the office, and a certain number of *gardes forestiers* grouped into *brigades* which exercise general supervision of the execution and direction of the work in the field. On the average, each *inspection* has four or five *brigades* each of three *gardes*.

The officers have a uniform, and their rank is distinguished by *galons* or stripes as follows: *Garde généraux* (2 *galons*), *Inspecteurs-adjoints* (3 *galons*), *Inspecteurs* (4 *galons*), *Inspecteurs principaux* (5 *galons*, of which 2 are in gold), *Conservateurs* (5 *galons* in silver).

FORESTRY EDUCATION

There is in France a school of higher forestry education, L'École nationale des Eaux et Forêts, established at Nancy, and a woodman's school at Barres, near Nogent-sur-Vernisson (Loiret).

The Nancy School, founded in 1825, provides the majority of the officers to the department. Direct competitive entry was abolished some forty years ago, and at present recruitment is from students who have a diploma of the National Agricultural Institute. In addition, two or three places are reserved annually for students of the Polytechnic School of Paris. The number of students

entering Nancy has varied considerably; at present it is about twenty, together with some students destined for Morocco and the Colonies.

The length of the course at Nancy is two years, and it extends to all branches necessary for forestry practice and administration: forest botany, silviculture, management, law, topography, zoology, geology, pedology, protection in mountains, &c. Its principal point is the importance laid on practical work; the winter term is devoted to work in the school, but the summer term is spent in practical work in the field. After various examinations, theoretical and practical, the students receive at the end of the second year the diploma of *Ingénieur des Eaux et Forêts*.

Unattached students, French and foreign, are allowed to take the course, and if they pass the necessary examinations they receive the diploma *Ingénieur civil des Eaux et Forêts*. In this manner some of the English foresters destined for the Indian Forest Service took the course at Nancy between 1867 and 1884.

The school at Barres receives each year a small number of *brigadiers* or *gardes* who, within certain limits of age and seniority, have undergone a special course. The length of the course at Barres is also two years, and the students receive a theoretical and practical training on such subjects as botany, silviculture, &c. At Barres there is also a school for the training of young *gardes* who have undergone a special course.

At Barres there is also the well-known arboretum.

FOREST RESEARCH

Forest research is centralized at L'École Nationale des Eaux et Forêts, which since 1882 has had a research and experiment station.

Reorganized by resolution of 15 June 1920, the station consists of four sections at the present time:

Section 1: forest sciences, forest meteorology, and forest pedology.

„ 2: forest botany and wood technology.

„ 3: zoology and water conservancy.

„ 4: restoration work in mountains.

Except for Section 1, which is placed under a chief with the rank of *inspecteur*, the professor of the subject directs the section with assistants.

The results of investigations are published in the *Annales de l'École Nationale des Eaux et Forêts et de la Station de Recherches et Expériences forestières*, which appears somewhat irregularly, but on the average once a year.

In each of the sections the subjects studied, or in the course of study, are as follows:

In the first section, a systematic study is made of the principal French forest species. For each of the important species a series of experiments has been established in its principal natural habitats in pure stands, naturally regenerated, and of different age-classes. For example, in the forest of Blois there is established three or four sample plots of 1 hectare in stands 30 years old, two in 60 years, two in 90 years, one in 120 years, and one in 150 years and over. These plots are measured periodically. In young stands, the thinnings are marked

to give different degrees of intensity, or different intervals in treatment, with a view to determining the maximum production compatible with good soil conditions and good quality of timber. At the present time, the number of such experimental plots is about 180, with a total area of 140 hectares. The total number of trees, numbered and periodically measured, surpasses 60,000. The following table gives some further details:

Species.	Experimental Plots.		Forest Regions.
	Number.	Area (ha.).	
Sessile oak	33	29.00	The neighbourhood of Nancy, Blois, Tronçais (Allier), and Cranou (Finistère).
Beech	47	32.83	Haye (Meurthe-à-Moselle), Darney (Vosges), Retz (Aisne), Eawy (Seine-Inférieure), Aigoual (Gard), Montagne Noire (Tarn), and Bize-Nistos (Basses-Pyrénées).
Silver fir	30	27.67	Vosges, Jura, Corbières, and Montagne Noire.
Scots pine	26	20.50	Artificially formed stands at Roumare (Seine-Inférieure), Chinon (Indre-à-Loire), and Vosges. Naturally regenerated stands at Montgenèvre (Hautes-Alpes), La Matte-des-Angles (Pyrénées-Orientales).
Maritime pine	12	6.50	Charente-Inférieure, Gironde, and Landes.
Spruce	10	9.00	Jura and Haute-Savoie.

Aleppo pine, larch, Mountain pine, ash, and the exotic species: *Abies grandis*, Douglas fir, Sitka spruce, Japanese larch, &c., are studied on a smaller scale.

Side by side with purely silvicultural studies, Section 1 also carries out investigations on the resin-tapping of pines, and meteorological observations.

Section 2 (forest botany and wood technology) investigates the technical properties of wood. In co-operation with Section 1, it has begun a study of the variation in mechanical properties with treatment. An investigation of the modification of properties resulting from fungal attack is being made, particularly the blueing of coniferous timber. A study is also being made of the changes in the properties of timber resulting from certain industrial treatments, such as impregnation with synthetic resins.

In the domain of forest botany, research has been undertaken on the geographical races of indigenous species. A certain number of old arboreta have been studied again, such as Amance (Meurthe-à-Moselle), Aigoual (Gard), and Le Riassesse (Aude); and others have been formed as at La Joux (Jura), or will be shortly established, particularly in Provence.

Section 3 has undertaken investigations on water-conservancy (monograph entitled *Hydrobiologie piscicole du Bassin de la Mortagne, de la Vezouse*) and entomology.

Section 4, devoted to protective work on mountains, is engaged on the study of glacial geology on Mont Blanc, contouring in different parts of the Alps and Pyrenees, and comparative investigations on the improvement of mountain pasture.

THE INTERNATIONAL UNION OF RESEARCH ORGANIZATIONS. NANCY CONGRESS, 1932

BY W. H. GUILLEBAUD

THE International Union of Forest Research Organizations held their second post-war Congress at Nancy in France in September 1932. The number of foreign delegates totalled only 45, and there was thus a much smaller attendance than at the previous Congress held in Stockholm. The largest individual delegation (apart from the French) was that from the British Empire, which sent 14 delegates representing Great Britain, Australia, Canada, India, Nigeria, Uganda, Cyprus, and Palestine. It will be recalled that the Union was reconstituted after the war when the Congress met in Stockholm in 1929 under the presidency of Professor Hesselman. A number of resolutions were passed at the Stockholm meeting relating among others to the questions of unification of research methods, origin of seed, treatment of leached, heather-clad soils, and the creation of an international forest bibliography. All these problems were ventilated again at Nancy, and though there may not be much actual progress to report, the discussions showed that the intervening time had not been wasted.

The work of the Congress was organized in six sections as follows:

Section 1. Forest Ecology and Silviculture.

- „ 2. Forest Utilization.
- „ 3. Tropical and Mediterranean Problems.
- „ 4. Reafforestation and Prevention of Erosion in the Mountains.
- „ 5. Pedology and Climatology.
- „ 6. Forest Protection.

The paper-reading programme was very heavy, especially in Section 1, which had as one of its main items the task of considering a series of papers describing the method of sample plot lay-out and measurement adopted in such countries as Great Britain, France, Prussia, Finland, Hungary, Holland, &c. It soon became apparent that the Congress was too unwieldy a body to discuss effectively a subject involving so many details, and a resolution was passed appointing a small sub-committee, consisting of Fabricius (Germany), Oudin (France), and Guillebaud (Great Britain), whose duty it will be to examine and correlate as far as possible the methods employed by the different research stations with a view to obtaining some agreement as to which are, in theory at least, the best methods.

Section 1 also considered the question of the standardization of locality descriptions, a subject which had been remitted to the present Congress from Stockholm. A resolution was passed recommending: (1) That the two schemes

prepared respectively by M. Kvapil (Czecho-Slovakia), for temperate and cold regions, and by Professor Pavari (Italy), for the Mediterranean region be completed by the scheme which is to be presented by the Dehra Dun Institute (India) for tropical regions; (2) That the three schemes be sent to the Permanent Committee of the Union for distribution, after approval, to all Forest Research Organizations.

The problems of the control of origin of tree seeds and of methods of testing seeds of forest trees were the subjects of two further resolutions which run as follows. As regards origin of forest tree seeds, the Congress recommended: (1) That research stations continue to exchange seeds for scientific purposes through the Secretary General of the Union; and (2) That governments, while retaining entire liberty in the matter of organizing control in their respective countries, be requested to adopt international standards for guaranteeing the control and origin of seeds. As regards methods of testing forest tree seeds the Congress recommended that a symposium should be held at the next Congress in which each country or State would briefly describe the best methods of testing forest tree seeds used in that country, together with such suggestions as the country might desire to make as to the effectiveness of the methods employed.

A further question discussed in Section I was that of National Parks. Professor Jedlinski of Poland and Professor Korstian of Duke University, U.S.A., were entrusted with the task of drawing up the final text of the recommendations to be submitted to the Congress at its Plenary Session.

The Second Section, dealing with Forest Utilization, passed the following resolutions, which were adopted by the Congress.

1. *Resin Tapping*. Whereas the tapping of pine for resin is of great economic importance, but is very complicated from the scientific point of view, the Congress draws the attention of governments interested in resin production to the desirability that tapping for resin should not be done without prior scientific research or at least research work performed concurrently with the practical work, but in all cases carried out by Forest Research Organizations, and makes the following recommendations:

- (i) That after consulting the Organizations concerned, the Permanent Committee should study and compare methods of investigation for the purpose of drawing up uniform rules for research.
- (ii) That communication of results obtained be facilitated by the exchange of reports made by technicians.

2. *Wood Tests*. In view of the great variety of methods now employed in physical and mechanical tests of wood, which render it difficult to compare the results of tests made in the various laboratories, the Congress recommends:

- (i) That the question of unification of methods, and presentation in figures of the results, be made a subject of study in the various research organizations of the Union.
- (ii) That it be submitted for discussion to the 1936 Congress for the purpose of arriving at a standardization of methods.

The Third Section, dealing with Tropical and Mediterranean problems, passed the resolution that the Congress recommends that the research stations of the regions concerned pay special attention to the morphological, physiological, and ecological study of the root-systems of the species forming the principal types of forest vegetation, particularly in arid, sub-tropical, and tropical regions.

The Fourth Section—Reafforestation and Prevention of Erosion in the Mountains—passed no resolution.

In the Fifth Section, on Pedology and Climatology, an interesting paper was read by Dr. Bornebusch of Denmark proposing an international scheme for the description of humus layers in the forest. Briefly summarized, two principal types of humus are recognized: Mull and Raw Humus. Mull consists of a single layer, but two sub-types are distinguished: True Mull and Superficial Mull. Raw Humus (Mor) consists of two layers: an upper layer known as the Fermentation Layer, and a lower layer known as the Humified Layer which can itself be subdivided into three types, namely, Fine Humus, Greasy Humus, and Fibrous Humus. Dr. Bornebusch's classification and terminology were adopted by the Congress.

A second subject dealt with by the Fifth Section was the study of podsolized soils, and the resolution was passed that in view of the importance of studying podsolized soils, especially those which have a layer of hard pan, and of discovering the best methods of cultivating such soils, a Committee should be appointed to make a special study of this question. The following were appointed to serve on the Committee: Dr. O. Tamm (Sweden); Dr. A. Nemeec (Czecho-Slovakia); Professor R. Lang (Munich, Germany); Professor L. G. Romell (U.S.A.); Dr. F. A. Weis (Denmark); L. G. Geerling (Holland); Professor Dr. Albert (Eberswalde, Germany); A. Oudin (France); K. Kirstein (Latvia); W. H. Guillebaud (Great Britain); Vilinsky (Russia).

It was decided to hold the next Congress in Hungary in 1936 under the presidency of Professor G. Roth.

EXCURSIONS

During the Congress two excursions were made, the one to the Forest of Haye in the immediate proximity of Nancy, and the other to the Forest of Ban d'Etival in the Vosges. In the Forest of Haye the delegates were shown the several stages in the conversion of coppice to high forest. The soil is calcareous and very variable in depth and fertility. The principal species are beech, hornbeam, oak, and ash. In 1860 some 12,500 acres out of the total of 16,000 acres were put under conversion, the process consisting in allowing the coppice to grow up but at the same time gradually reducing the number of shoots on the stobs. When the trees are from 60 to 70 years old preparatory seeding fellings are made in which all or most of the hornbeam are removed. The regeneration fellings extend over about 30 years, by the end of which time a virtually pure crop of beech results. In the opinion of some of the delegates the process might

have been accelerated by heavier thinning in the preliminary conversion stages. The beech regeneration was admittedly very successful.

Excursion to Ban d'Etival. This excursion had as its primary object the inspection of an investigation carried out by the research station at Nancy into methods of calculating the yield of selection forests of Silver fir in the Vosges. The work has been in progress for nearly fifty years, and a report was recently published by M. Oudin in vol. iv, No. 1, of the *Annales de l'École Nationale des Eaux et Forêts*. It appears that each of the three methods employed gave satisfactory results and that at the present time the stands approach fairly closely to the normal growing stock as determined locally.

The principal species in this part of the Vosges is the Silver fir, but beech is an important subsidiary species, forming almost pure stands on some of the ridges, and tending to get the better of the Silver fir on the northern slopes. A small admixture of beech is welcomed by the foresters, but the timber is almost invariably red-hearted and so of very poor quality. Both Silver fir and beech regenerate with great freedom, and the climatic conditions are evidently optimum for the former species. *Dreyfusia* is virtually absent, a fact of some interest in view of the damage being caused by this insect to Silver fir forests in the Black Forest and Bavaria. The rainfall is 60 inches and well distributed over the year; atmospheric humidity is also high. The ground vegetation consists largely of bilberry with *Aira flexuosa*, *Oxalis acetosella*, male fern, and other plants familiar to British foresters. An interesting and rather common plant is the purple-flowered composite *Prenanthes purpurea*, which we were informed is an indicator species characteristic of the Silver fir habitats in France.

A very fine stand of mature Scots pine was also visited, this species is more or less confined to southern slopes. The race was termed by M. Guinier the Vosges race of Scots pine and is an *élite* type characterized by the straight stems, small, short lateral branches, and the bark with very large smooth scales, the so-called 'Snake Skin' bark. Strip regeneration fellings were in progress, regeneration was rather patchy, being abundant where the ground was fairly bare but scanty or non-existent among heavy weed growth.

The rotation for both Silver fir and Scots pine was 150 years.

Excursion to the Mediterranean Region. The dominant interest of the tour to the Mediterranean region, which took place after the Nancy Congress, was rather botanical than silvicultural, involving a demonstration of the zonation of forest types with increasing elevation. The first area visited, Mont Ventoux, a semi-isolated mountain not far from Avignon and rising to 6,200 feet above sea-level, showed this phenomenon particularly clearly. Five zones were distinguishable as follows:

1. Upper Mediterranean, 1,300–2,200 feet. *Quercus ilex*.
2. Low Mountain (Basses Montagnes), 2,200–4,200 feet. *Quercus lanuginosa*.
3. Mountain, 4,200–5,000 feet. Beech.
4. Sub-alpine, 5,000–5,900 feet. *Pinus uncinata*.
5. Alpine, above 5,900 feet. Alpine herb flora.

The lower limit of the beech zone can be correlated closely with the lower

level of the mists and fogs which frequently cover the upper part of the mountain during the spring and summer months.

The original forest appears to have been almost completely destroyed by the local population, grazing, &c., and as recently as 100 years ago the greater part of the mountain (above 2,200 feet) was described as devoid of tree growth. Active measures of reafforestation were undertaken from 1860 onwards, and a total of over 11,000 acres has been established with trees. Natural forest appears to have re-established itself over a further area of 13,000 acres.

The principal species used in the replanting were the two oaks, *Quercus ilex* and *Quercus lanuginosa* (the latter species is considered by some botanists to be merely a variety of *Quercus sessiliflora* but has a very different habit and rate of growth), which were established by patch sowing, *Pinus uncinata*, also direct sown, and sundry other conifers such as Maritime pine, Aleppo pine, Austrian pine, and Atlantic cedar. Of these latter the most interesting is the Atlantic cedar, which was introduced about 1860-5 by direct sowing in mixture with pines between the elevation of 1,700 and 2,800 feet, i.e. in the zone of *Quercus lanuginosa*. Originally established over an area of 380 acres it has now spread naturally, invading the adjoining pine stands, and now occupies an area of nearly 500 acres with stands over 30 years of age. Abundant natural regeneration was seen and, at the appropriate elevation, it appeared to be much the most successful conifer on the dry limestone debris of which the slopes of Mont Ventoux are largely composed. Some 900 lb. of seed of *Cedrus atlantica* are collected annually in the forest, the seed is not easy to extract and it is the practice to steep the cones for a day in water before heating them for extraction. A small sample plot established in a 35-year-old pure stand of cedar gave the following data:

No. of Trees per acre.	Mean Height. (feet)	Mean Q.G.	Volume Q.G. per acre.	Mean annual increment during past 5 years.
650	50	7½	1,300	50

When afforesting bare limestone slopes with cedar it is also the practice to use plants. The seed is sown in limestone rubble (to check excessive tap-root formation), lined out at the end of the first year, and planted out as 1-yr. 1-yr. transplants.

The second excursion was to Mont Aigoual (5,100 feet), a mountain towards the southern end of the Cevennes Range and composed mainly of granitic rocks and metamorphic schists. The rainfall varies with the elevation, ranging from 60 to 90 inches, snowfall is heavy in winter, and violent windstorms from the north-west (mistral) are of frequent occurrence.

The same natural zonation is found here as occurs on Mont Ventoux, the lowest or Mediterranean zone being characterized by *Quercus ilex*, above this comes the Low Mountain zone with *Quercus lanuginosa* on calcareous soils and Sweet chestnut on siliceous soils, the highest zone is that of the beech, which begins at an elevation of about 3,000 to 3,300 feet.

As a result of excessive utilization, combined with the grazing of goats, the

greater part of the mountain was denuded of forest by the middle of the nineteenth century. Reafforestation started in 1860 on a modest scale, and in 1882 extensive acquisitions of land were made by the State, nearly 35,000 acres being purchased at a cost of about £3 per acre.

The general procedure was as follows: Below 3,600-foot elevation, on bare soils, direct sowing of erect mountain pine and planting of Atlantic cedar, Corsican pine (on siliceous soils), and Austrian pine (on calcareous soils); sowing of *Quercus lanuginosa* and planting of Sweet chestnut on the south side of the mountain. On sheltered slopes spruce and larch were planted. Some Silver fir was introduced where beech coppice was present to provide shelter. Above 3,600-foot elevation the erect Mountain pine, established by patch sowing, was the principal species used; a considerable amount of Scots pine was also sown, but with poor results. The ultimate intention was to introduce more valuable species, such as Silver fir, spruce, and larch under the shelter of the pine crop, wherever the conditions are sufficiently favourable. Approximately 6,000 plants per acre (inclusive of beating up) were used over the 10,000 acres of forest re-established by planting. A large proportion of this area consists now of dense coniferous plantations from 30 to 50 years old, most of which had not until quite recently been thinned. The introduction of a regular system of management has been the chief task of the local staff during recent years. The forest has been divided up into compartments, and the whole area is being worked on a 10-year improvement cycle which consists partly of thinning operations and partly of group fellings with a view to natural regeneration.

On Mont Aigoual as at Mont Ventoux the Atlas cedar gives promise of being a very useful species in the lowest zone, regenerating freely under the light shelter of pine and quickly colonizing blank areas in the forest. The outstanding species at moderate elevations appeared to be Norway spruce, but some excellent stands of Corsican pine were also seen. Between 3,600 and 4,600 feet perhaps the most successful species was the erect form of Mountain pine, *Pinus montana uncinata*, which has formed dense pole stands of excellent quality. Regarding this the President of the Union, M. Guinier, expressed the view that the *uncinata* form should be raised to specific rank and that the specific name *montana* should be dropped, *P. mugho* representing the dwarf form and *P. uncinata* the erect form. Seen side by side, as the two trees can be seen in many parts of Mont Aigoual, they are certainly very distinct apart from any question of habit, the *uncinata* with longer needles and horizontal or almost ascending cones, while *mugho* has short needles and downward hanging cones. Except for covering windswept ridges it was considered that *P. mugho* has no merits as a forest tree.

The third excursion took the party to the arid calcareous foot-hills above Toulon, where, in the Forest of Ollioules, are examples of the Lower Mediterranean zone, characterized by the dwarf *Quercus coccifera* and the Aleppo pine, *Pinus halepensis*. The work of restoration is here rendered peculiarly difficult by the shallow rocky nature of the soil, the frequent occurrence of fires, and the

invading tendency of the *Q. coccifera* which, when it becomes too dense, prevents the Aleppo pine from establishing itself. The forest has been treated hitherto under the even-aged system with a rotation of 45 years, all timber over 8 inches diameter being used for barrel staves or box boards. Experience having shown that the even-aged system does not work satisfactorily under the difficult conditions prevailing, it is proposed to adopt the selection system in future.

The State forest of Montrieux in the upper valley of the Gapeau was also visited. The elevation of this forest ranges from 600 to 2,500 feet; the soil is very variable, consisting in part of sand and in part of calcareous loams, but on the whole is of good quality and favourable to tree growth.

The forest as a whole has had a much less chequered history than most of the other forests in the Mediterranean region, thanks probably to the protective influence of an old monastery situated in the heart of the woods. Largely perhaps as a result of this protection the forest zones are less well defined than in many other forests of the region and there is a general intermingling of the Upper Mediterranean zone—*Quercus ilex* and *Pinus halepensis*—with the foot-hills zone—*Quercus lanuginosa*. The forest is treated under a coppice rotation of 24 years, the produce being used chiefly for the manufacture of charcoal.

The Massif de l'Esterel north of St. Raphael was the object of the fourth excursion. The Esterel forms a tumbled mass of hills and valleys, the hills rising to an elevation of 2,000 feet, composed largely of volcanic and schistose rocks yielding a thin and somewhat poor soil. The climate is hot and the summer very dry; the mean annual rainfall of 38 inches is fairly high, but on the average rain falls on only 58 days during the year, of which nearly half are in the autumn. Sufficient rain normally falls during the spring to enable the vegetation to resist the summer drought. The dominant species in the 14,000-acre State forest are Maritime pine and Cork oak with a very small proportion of Aleppo pine and *Quercus ilex*. In former times the forest was worked on the uniform system with a rotation for the Maritime pine of about 100 years, the barking rotation for the Cork oak ranging from 9 to 12 years according to the rate of growth. Three large fires, in 1838, 1854, and 1877, upset the regular management of the forest, and in 1906 a group selection system was introduced for the pine with a felling cycle of 16 years. Further fires took place in 1918, when the staff was depleted as a result of the war and five-sixths of the forest was destroyed, in 1923, and again in 1927. From 1838 to 1931 101 fires have occurred. Of these:

57 burnt less than 2½ acres.					
20 burnt from 2½ to 12 acres.					
5	”	”	12	”	24
10	”	”	24	”	240
4	”	”	240	”	2,400
,, and over.					

In 1854 two incendiary fires burned 6,000 acres, and in 1877 another

swept over 4,000 acres of the State forest. The fire of 1918 originated from military camps in the forest.

The extreme susceptibility of the forest to fire is ascribed to three main causes: (1) the resinous character of the pine; (2) the nature of the undergrowth—dense shrubby maquis; (3) the summer heat and the strong dry winds prevalent during the season of fire danger.

Elaborate measures have been taken to protect the forest from fire. The road system consists of 30 miles of unmetalled but motorable roads 12 feet wide, 88 miles of rides 8 feet wide, and 128 miles of paths 3 feet wide; in all cases the roads, rides, &c., are bounded by ditches. There are eleven Maisons Forestières scattered through the forest, each with a workman's bothy attached; and in addition there are three bothies with accommodation for five or six men. A telephone system with a total length of 30 miles links up the foresters' houses, look-out posts, and the Inspecteur des Eaux et Forêts, head of the Cantonnement at Fréjus. There are two look-out posts, one on Mont Vinaigre in the Forêt de l'Esterel and the other (only established within the last few years) on Le Grand Courrent in the State forest des Maures, some 10 miles apart; each post is provided with a sighting instrument revolving round a circular scale so that bearings can be telephoned to the head office and the approximate position of a fire determined.

The equipment provided consists of:

(a) Two one-ton lorries, one stationed at Malpey and the other at Gratadis (Brigade Head-quarters). Each lorry seats nine men in addition to the driver. There are lockers under the seats containing sufficient tools to equip ten men, the tools comprising entrenching mattocks, bill-hooks, axes, pickaxes, and wide, short-toothed iron rakes, also two cans for drinking-water. Each vehicle is provided with a trailer with 22 gallons of drinking-water and 44 gallons of water for use in two sprayers. A third lorry, stationed at Fréjus, is in reserve in case of need.

(b) Two motor-cycles for patrolling the borders of the forest and for immediate action on the outbreak of a fire.

(c) A motor-boat with four seats for watching the coast zone and the railway.

A system of fire-lines has been laid out with great care. These consist in the first place of boundary fire-lines 66 feet in width; there are over 25 miles of such lines. Secondly, there are 63 miles of fire-lines, 33 feet wide, on each side of the principal roads and paths. Thirdly, the forest is divided into four blocks by lines 66 feet wide crossing the forest and so laid out as to offer the best chance of confining a major fire to one of the blocks. The fire-lines are kept completely clear of undergrowth, the work of clearing being repeated every three years.

The cost of fire protection was given as 8 francs (about 2s.) per acre per annum.

The basic ideas on which the whole system of fire control rests are (a) the immediate discovery and location of any outbreak of fire, and (b) to attack the fire at the earliest possible moment after it has been located. Counter firing is regarded as a measure to be adopted only as a last resort in the case of a major

fire urged on by a violent wind. It is not to be used except at nightfall, at a distance of some hundreds of yards in advance of the fire, and then only when it is evident that the fire cannot be checked by any other means.

In their final excursion the delegates visited the communal forests of the Escarène and of the Col de Braus in the Maritime Alps to the north of Nice and the communal forest of Èze between Nice and Mentone. This region differs from Provence partly in enjoying a somewhat higher rainfall and partly in the absence of the dry mistral winds which are in a great measure deflected by the Esterel hills. These two facts account for the more luxuriant vegetation and in particular for the presence of certain species such as *Ostrya carpinifolia* and *Fraxinus ornus*, which are here at the western limit of their natural range.

Broadly speaking, the same main vegetation zones occur as in the other districts visited in the earlier excursions. The Lower Mediterranean zone has as characteristic tree species the Aleppo pine on calcareous and the Maritime pine on siliceous soils. It is a curious fact that *Quercus coccifera*, which is such an important associate of Aleppo pine farther to the west, does not occur at all in the region of Nice. *Quercus ilex* is the typical species of the Upper Mediterranean zone, but Maritime pine plays an important part where there is not too much lime in the soil. Above comes the Low Mountain zone with *Quercus lanuginosa* and on calcareous soils *Ostrya carpinifolia*. The latter is worked as coppice on a 20-year rotation, the produce being utilized for the manufacture of charcoal. The characteristic species of the uppermost or Mountain zone are the beech and the Scots pine. Norway spruce, a species belonging to the still higher Sub-Alpine zone, which was not represented in the area actually visited though it occurs in the higher mountains to the north, occurs here and there in the forests on fresh soils with a northerly aspect.

The conifer and beech forests in the Mountain zone are managed on the selection system.

The delegates were also shown some examples of torrent control and afforestation on the steep denuded slopes of the valleys of Paillon and Careï. These works have been extremely costly, expenditure ranging from £10 to £44 per acre, but in general they have succeeded in preventing disastrous floods with consequent damage to property. The torrent work consists in the usual stepping of the floor of the stream-bed with masonry walls, stones, or faggots. As soon as partial stabilization is effected in this way patch sowings are made on the hill-sides, using Maritime pine, Aleppo pine, Pubescent oak, Sweet chestnut, &c.

The return journey from Mentone to Nice was memorable for the wonderful views obtained from the Grande Corniche road with its sea and mountain scenery. The delegates dispersed from Nice on 18 September.

WEEDS IN FOREST NURSERIES

EDITED BY H. M. STEVEN

THE following article is published at the request of the Forestry Commissioners. It is based on data supplied by their Deputy Surveyors and Divisional Officers, to whom acknowledgement is made.

Weeding costs average about 30 per cent. of the total cost of raising nursery stock, and undoubtedly provide a field for improvement. *Weeds of Arable Land*, by H. C. Long, Ministry of Agriculture and Fisheries' Miscellaneous Publication, No. 61, deals comprehensively with weeds from the agricultural point of view, and the present article is written with that publication as a background.

CLASSIFICATION OF WEEDS

Perennial and Annual Weeds. The weed flora varies from nursery to nursery, and is conditioned by the soil, the climatic conditions, and the use of the surrounding land. A complete list of plants which are weeds in forest nurseries in Great Britain would include a major part of the British flora. A few species, however, are both common and troublesome in a large number of nurseries, either because of their wide distribution, their association with types of land often used for forest nurseries, or their inherent characteristics. The following is a list of these species, annual and perennial:

ANNUALS

Spurrey (*Spergula arvensis* L.)
Annual Meadow Grass (*Poa annua* L.)
Groundsel (*Senecio vulgaris* L.)
Knotgrass (*Polygonum aviculare* L.)
Chickweed (*Stellaria media* L.)
Shepherd's Purse (*Capsella bursa-pastoris* D.C.)

PERENNIALS

Couch (*Agropyrum repens* Beauv.)
Onion Couch (*Arrhenatherum avenaceum*
Beav. var. *bulbosum* Lindl.)
Sheep's Sorrel (*Rumex acetosella* L.)
Creeping Buttercup (*Ranunculus repens* L.)
Creeping Thistle (*Cirsium arvense* Scop.)

If on the formation of a nursery the land is foul with perennial weeds, then the first step should be their thorough eradication. The economic production of nursery stock is impossible otherwise, hence a permanent nursery should be reasonably free from the worst perennial weeds. Annual weeds, on the other hand, have to be dealt with year by year, and are a constant menace.

Root Development. Nursery weeds can also be usefully classified from the point of view of root development. Some species develop a larger root system than others, hence should be removed before they do so, because later they can only be got out with much damage to the trees. According to experience in the Forest of Dean, weeds were classified from this point as follows, category I being the most dangerous and III the least:

I	II	III
Field Bindweed (<i>Convolvulus arvensis</i> L.)	Creeping Buttercup (<i>Ranunculus repens</i> L.)	Heartsease (<i>Viola tricolor</i> L.)
Broad-leaved Plantain (<i>Plantago major</i> L.)	Sandworts (<i>Arenaria</i> spp.)	Cranesbill (<i>Geranium</i> spp.)
Couch species	Marsh Cudweed	Chickweed
Docks (<i>Rumex</i> spp.)	(<i>Gnaphalium uliginosium</i> L.)	(<i>Stellaria media</i> L.)
Dandelions (<i>Taraxacum officinale</i>)	Ribwort Plantain (<i>Plantago lanceolata</i> L.)	Groundsel (<i>Senecio vulgaris</i> L.)
Creeping Thistle (<i>Cirsium arvense</i> Scop.)	Spurrey (<i>Spergula arvensis</i> L.)	Pimpernel (<i>Anagallis arvensis</i> L.)

Spread and Establishment. Weed species can also be usefully considered in relation to their ability to spread rapidly and establish themselves *en masse*. The characteristics which enable this to be done are, firstly the power of great or continuous seed production, or ease in vegetative reproduction, and secondly tolerance of soil conditions. On rich soils conditions are suitable to a large number of species, and there is typically a rich weed flora, while on poor soils a smaller number of species can grow, and this tends to mass attack of these few species. Examples of the species which tend to become epidemic are Spurrey, which has powers of great and continuous seed production and is very tolerant of poor soil conditions, and Sheep's Sorrel, which propagates freely vegetatively and tolerates soil acidity. Generally speaking the mass attack species are the most dangerous.

SOURCE OF INFECTION

Cultural History of Site. The cultural history of the nursery site is important in relation to subsequent weeding costs. There is always difficulty in securing suitable nursery sites, and it is rarely possible to give due weight to weediness. From a cost point of view, however, a site clean and in good heart is worth much more than, say, a piece of derelict arable land, foul with weeds. Experience has shown that the weeding costs are very high in nurseries which were foul when formed: it takes a number of years to get such nurseries clean.

Surrounding Conditions. The surrounding conditions are also important. Where the adjoining land is arable in a poor state of cultivation, or weedy grassland, then the cost of weeding remains much higher than where the surrounding land is clean or woodland in close canopy.

It is preferable to keep the whole nursery area free from weeds, and due attention is not always paid to weediness of fence sides, paths, verges, &c., and these not only increase the spread of weeds but also harbour cockchafer larvae. It is essential to see that weeds do not seed in any part of the nursery.

Manure. Farm-yard manure is a fertile source of weed contamination, and some prefer not to use such manure at all. Unless broad-leaved humus is available in sufficient quantity, the use of farm-yard manure is, however, essential if fertility is to be maintained. Care should be taken to examine the manure before purchase. Well-rotted manure is much less likely to be dangerous than

fresh manure, and can usually be used safely at once, but where there is doubt, for example with manure made with hay other than from clean layers, the manure should be clamped in autumn and left as long as possible. Manure made from bracken is suitable for the heavier soils.

Compost Heaps. Manure from weed compost heaps is responsible for many troubles. The formation, treatment, and use of compost heaps require care. In the first place, perennial weeds, and especially the Couch species, should not be put into compost heaps but burned. There is abundant evidence that it is almost impossible to kill Couch grasses by compost heap treatment. A certain proportion dies and rots, but sufficient remains alive to make its inclusion unwise.

If the rule is followed that on the formation of a nursery the perennial weeds are eradicated in the first season, then it becomes possible to keep such dangerous perennial weeds out of the compost, because in subsequent years there will be only a small proportion of these species.

When the weeds can be got up without much soil it is recommended that they be laid out in layers about 6 inches thick and heavily sprinkled with ammonium sulphate ($\frac{1}{4}$ to $\frac{1}{2}$ lb. to square yard) and an equal quantity of quicklime or ground limestone before the next layer is laid on the top. Such a heap will heat up rapidly, rendering root stocks and seeds harmless before the next season.

Where much soil is present, for example in a wet season, or on the heavier soils, a slower method of rotting is safer. The heaps should have a heavy admixture of quicklime to keep conditions favourable for rotting processes. Such heaps should not be used for two years and turned over at least once during the period.

It should be stressed that heavy weed contamination is inevitable from weed composts unless there has been treatment by sulphate of ammonia and lime. Before using a compost heap it is wise to open it up to see what amount of living seeds, &c., remain. If present they germinate quickly.

METHODS OF DEALING WITH WEEDS

On Formation of Nursery. As many different types of land, with varying cultural histories, are taken for nurseries, no comprehensive outline of methods of dealing with existing weed flora can be attempted. Arable land, clean and in good heart, can sometimes be utilized forthwith, although it is usually preferable to begin with a cleaning crop. The commoner categories, foul arable, poor grass-land, and waste land, have certain features in common. It should be stated at once that it is not considered economic in the long run to utilize such types for lining out or seed-beds before the weeds are effectively dealt with, and this may take one or more seasons. In the absence of any appreciable quantity of the worst perennials, such as the Couch grasses, Creeping Thistle, &c.—and this can only be determined by careful examination—ploughing in autumn to the limit of the developed soil will be efficient in most instances in

smothering and rotting the bulk of the weeds. In the spring cross-ploughing, cultivating, and harrowing will be sufficient preparation for a cleaning crop. In the case of grass-land difficulty is sometimes experienced in getting the sod to rot. On the less acid soils rotting usually takes place during the winter, but on acid soils rotting is often slow, and it may be necessary to lime before cross-ploughing to accelerate decomposition. On sites foul with couch and similar perennial weeds shallow ploughing followed by cultivation and harrowing, or surface cultivation by a grubber, and the heaping and burning of the material, is best. This may have to be repeated several times during the summer, and more than one season's cultivation may be necessary. In especially difficult cases hand forking, heaping, and burning may be necessary, particularly with Onion Couch (*Arrhenatherum avenaceum*); the strings of 'bulbs' of this species are easily broken up and spread by cultivation, hence forking and hand picking is the only satisfactory method of eradication.

Weeding Land preparatory to making Seed-beds, lining out, and sowing soiling Crops. Before ploughing or digging, some cleaning is usually necessary to get out perennial weeds, particularly those with root stocks or underground stems. If the land is in reasonable condition it is preferable to do this by hand, going over the land with a fork and forking up, collecting, and burning such weeds. It is a mistake to turn in weeds which come up freely even when buried, such as the Couch species, Creeping Thistle, Creeping Buttercup, Sheep's Sorrel, and Dandelion.

Seed-beds. In the preparation of seed-beds, final cleaning can be done when working up the tilth. A three- or five-tined cultivator (Buco type) is a useful tool for this purpose. All perennial weeds should be got out of seed-beds.

The fine tilth necessary for the raising of coniferous species makes an excellent seed-bed for all weeds. Many weed species germinate rapidly, and the first weeding is not only costly but, where the slower germinating trees species are being raised, for example Douglas fir and Sitka spruce, considerable damage results from the weeding. Various means have been tried to reduce weeding in seed-beds, and the following brief description and comments may be of value:

(1) There is a widespread belief that drill sowing results in lower weeding costs than broadcast. This is true for nurseries where weed growth is heavy, and it is to be recommended for such because the advantage of hoeing is then large. In nurseries where weeds can readily be kept under, although the weeding cost per 100 square yards is lower for drill than for broadcast beds, the cost per 1,000 plants, which is the true criterion, is higher owing to the fewer plants per square yard.

(2) At the Bagshot nurseries a method of advance preparation of seed-beds was practised. These were left for two to three weeks, and when the weeds germinated the beds were hoed and the tree seed subsequently sown. This necessitates late sowing so as to secure the germination of the weeds. This was overcome at Bagshot by pregermination.

(3) Weed-free sand, e.g. from a pit, has been used for the covering of seed, particularly in the drill method. Where a suitable type of sharp sand is avail-

able this is to be recommended, both because it tends to reduce weeds in the actual drills and because it accelerates and increases germination. This method is practised in at least one large nursery.

(4) The treatment of covering soils and seed-beds with chemical solutions has been practised. In this country the best results have been obtained with a 1 per cent. solution of copper sulphate (approximately $1\frac{1}{2}$ oz. per gallon). Where soil is brought in for covering seed the treatment of this soil with such solution, allowing the soil to dry out, has given good results.

(5) The blow-lamp treatment of seed-beds, first introduced by Ben Reid & Co., Aberdeen, has proved successful under certain conditions. A Primus blow-lamp with one or two burners is used to go over the seed-beds just before germination of the tree seeds begin, i.e. one to two weeks after sowing, depending on the species and weather conditions. A tank with two burners requires three men, one with the tank in a barrow or special trolley, and one man to each burner. The treatment gives the best results where there is mass infection of annual weeds such as Spurrey and Annual Meadow Grass. Under such conditions the first and most troublesome weeding is avoided and the second reduced. Care is always necessary in the use of this method because in warm moist weather germination may proceed quickly and the swelling seeds be destroyed.

Broadcast beds have to be weeded by hand. The ideal to be arrived at is the removal of the weeds in the seedling stage, before the root systems become developed. The number of weedings and cost varies widely with nursery and weather conditions. Under very favourable conditions only two weedings may be necessary in 1-year seed-beds, but the number may be as high as five. If the beds are reasonably stocked, weeding in the second year is less serious, and one to three times is enough. Weeding in beds to be lifted is somewhat neglected towards the end of the season, but it is important to see that the weeds do not seed.

In drill sowing, solid hoes, 3 inches wide for drills spaced 4 inches apart, and *pro rata*, are generally used. Except in wet seasons, hoeing is sufficient to kill the weeds. Hand weeding in the actual drills is usually necessary in addition.

Alleys or paths between seed-beds should be kept clean. This is best done by turning over periodically with a spade.

Transplant Lines. A wider range of tools is available for weeding lines: one and two wheeled Planet Juniors, Dutch hoes, draw hoes, and a type with a draw hoe on one side and two tines on the other, the tines being $2\frac{1}{2}$ to 3 inches apart and 5 to 6 inches long. The three- or five-tined cultivator, already referred to, is useful for going over the lines early in the season to kill germinating weeds and to loosen the soil which has become consolidated by rain, thus reducing evaporation. An early weeding of this kind can be done before the seed-beds need attention, and this aids the organization of the nursery work. The alternate use of such a cultivator and an ordinary hoe has also been recommended. The number of weedings required in a season varies, but two to three generally suffice.

The particular tools used depends largely on local custom, for example,

Dutch hoes are common in Scotland, and a skilful man can operate two at a time walking backwards, thus doing two rows, while draw hoes are the common type in England.

The combination draw hoe with tines on the back of it has been found useful at Tintern. The tines are used when encountering patches of Couch grass and similar weeds to get them up entire. Planet Juniors are useful except on stony soil, when they tend to slip and cut the plants. In practised hands they are undoubtedly an advance on ordinary hoes.

Soiling Crops, Agricultural Crops, and Fallowing. One of the most important methods of keeping a nursery clean is the systematic use of soiling or green crops. It is also essential to have a rotation such as this to deal with the different species of chafer larvae, where they are troublesome. The best form of rotation depends on the local conditions and, for example, the particular species of chafer present, if any, and the length of their life-cycle, but generally the order for each section of the nursery should be: soiling crop, transplants, seed-beds, soiling crop. In long established forest nurseries, seed-beds can follow soiling crops, but in the newer nurseries the inoculation of the soil with mycorrhiza from the transplants makes the recommended rotation more desirable.

Local conditions also determine the best soiling crop to use. On the light and poorer soils, mustard and buckwheat have given satisfactory results, while on the heavier and more fertile soils lupin, preferably the yellow lupin, is to be recommended. There is room for local experiments, however, to extend our knowledge of soiling crops.

The amount of seed to sow per acre also varies with local conditions, and no definite amount can be laid down. Where germination and growth is normal, and mustard and lupins should reach 2 to 3 feet in height, 20 to 25 lb. of mustard seed and 100 to 120 lb. of lupin seed per acre give satisfactory results.

Soiling crops frequently grow too poorly to smother weeds, and this is generally due to lack of manuring. A nursery which is sufficiently fertile to grow reasonable crops of trees may be too infertile to grow crops of mustard and lupin without manuring. The soil should be dressed with the usual artificial fertilizers, and, for average conditions, 2 cwt. sulphate of ammonia, 4 cwt. basic slag, and 4 cwt. sulphate of potash, all per acre, should give satisfactory results with mustard, while for lupins the latter two plus 5 cwt. of ground limestone or quicklime are recommended. Unless where organic material decomposes very slowly, or it can be obtained readily in quantity, it is better to apply broad-leaved humus and farm-yard manure direct to the seed-beds and transplant lines rather than to the soiling crop.

It is essential that the soil be properly cleaned before the soiling crop is sown. It can be sown at any time up to midsummer provided it is not too dry to secure germination, hence there is time to do this after the spring work is finished.

For a long period a common method of cleaning a forest nursery was to include an agricultural crop, particularly potatoes, in the rotation. Some ten

years ago there were several outbreaks of *Rhizoctonia* disease on coniferous seedlings, which were traced to infection from diseased potato tubers, and this led to the reduced use of this crop. In several respects potatoes are the most suitable agricultural crop for cleaning purposes, and it is considered that undue weight has been given to the disease danger. Provided all the tubers are got out of the ground, and a crop of tree transplants follows before the land is again used for the raising of seedlings, the risk is not serious.

Except on the formation of a nursery, fallowing for a whole season is not now generally practised because it is possible to clean for three months and then sow a soiling crop, say in July. In weedy nurseries, however, it may still be necessary to fallow for a whole season in order to get it thoroughly clean.

Roads, Paths, &c. The cost of keeping these free from weeds is a considerable item. Full use is rarely made of the ordinary weed killers: arsenic compounds, sodium chlorate, and common salt. An extension of their use would be advantageous.

THE INK DISEASE IN ENGLAND

BY W. R. DAY

(Imperial Forestry Institute, Oxford)

PHYTOPHTHORA CAMBIVORA (Petri) Buisman, the fungus causing the ink disease of chestnut, has a very wide distribution. In its southern limit it has been recorded killing walnut trees in Tasmania, while its northern limit, as at present discovered, is in western England. Between these limits it, or very closely related varieties or species, occur on many species of host, always causing the same type of damage, namely a root-rot which, if sufficiently extensive, kills the tree. It is impossible to say how long the disease has been in England or whether or not the fungus is indigenous. It has been proved to exist here only within the last two years, but in one locality at least is known to have occurred for some time previous, the length of which cannot be determined. It seems to be quite certain, however, that in its present virulent form the disease is of recent occurrence.

So far *Ph. cambivora* has been discovered in Hampshire and Herefordshire on chestnut and in Somersetshire on beech. The fungus is very virulent and destructive on the chestnut, but so far has not occurred in an epidemic manner on beech. It is not known what part the fungus plays in the extensive and wide-spread die-back of beech that has been taking place for some years past, but it is believed that other factors, both climatic and edaphic, are of much greater importance. Inoculation experiments have proved the parasitism of both the beech and chestnut strains of the fungus, and so far have shown the beech to be more resistant than the chestnut to either strain. In view of the known polyphagous nature of this parasite it is not improbable that it can attack other species than those on which it has hitherto been discovered. It is probably virulent, however, only under particular conditions: for instance, soils that are wet and difficult to drain, or on account of their heavy nature hold water for a long time, are particularly favourable to it. There is so far no reason to believe that, except in the case of chestnut, any severe destruction will be caused, but a strict watch is being kept in order that the progress of the disease may not be lost sight of.

In France *Castanea crenata* Sieb. et Zucc. has been found to be resistant to ink disease, and because of the importance of chestnut in the south of England it has been felt desirable to test the suitability of this species for this country. The Forestry Commission are therefore establishing sample plots of suitable varieties in the south of England, and in time these should yield valuable information both as to the suitability of the trees to the climate and the rate of timber production and general growth.

THE FORESTRY SUB-SECTION OF THE BRITISH ASSOCIATION, YORK, 1932

MR. T. B. PONSONBY was chairman of the Department of Forestry, K*, and Dr. E. V. Laing, Secretary.

The following is a list of authors and titles of papers:

- 'A System of Forestry for the British Isles', Mr. T. B. Ponsonby, J.P., D.L.
'Discussion on Exotic Conifers and the factors governing their Introduction':
 (a) 'Conifers in Scotland', Colonel F. R. S. Balfour.
 (b) 'The Silvicultural value of Exotic Trees in Ireland', Mr. A. C. Forbes, O.B.E.
'The Cricket Bat Willow', Dr. J. Burt Davy.
'The Wood of the Sterculiaceae', Miss M. M. Chattaway.
'The Enemies of the Elm Bark Beetle', Dr. W. B. R. Laidlaw.
'Research on Wood-working Machinery', Mr. P. Harris.
'Recent Advances in the Study of the Chemistry of the Hemicelluloses of Wood', Dr. M. H. O'Dwyer.

With the Section of Botany, K:

- 'The Living Tree', Prof. J. H. Priestley (Presidential Address).
'The Study of Wood Anatomy as a link between Botany and Forestry', Mr. B. J. Rendle.
'Multiperforate end-walls of Vessel Segments', Dr. L. Chalk.
'The Effect of Nutrition on the Relative Root and Shoot Development of Forest Trees', Mr. R. M. Aldrich-Blake.

SOCIETY'S AND OTHER NEWS

FIFTH ANNUAL EXCURSION

ARRANGEMENTS were made to hold this in September notwithstanding the small number enrolled. Almost at the last minute, however, both the President and the Convener of the Meetings Committee found themselves unable to attend, and as none of the other senior office-bearers could take their places it was thought better to postpone the excursion until next spring.

The Council have now decided to hold it either in May or in early July, according to the preference of the members as indicated by a ballot. As a result of this May has been provisionally selected. Members will be notified in due course of the date selected, and it is hoped that many additional members will enrol when details are made known.

SIXTH ANNUAL GENERAL MEETING

By the courtesy of the Director, the Society's Sixth Annual General Meeting will be held at the Royal Botanic Gardens, Kew, Surrey, on a date in February or March 1933 which will be fixed later and intimated to members in good time.

ELECTION OF OFFICE-BEARERS AND COUNCILLORS

THE following were duly nominated for election to office at the Sixth Annual General Meeting, and as there is no competition for any office there will be no ballot this year and the candidates will be formally elected at the meeting: *President*: William Dallimore V.M.H., Royal Botanic Gardens, Kew, Surrey. *Vice-President*: Sir Alexander Rodger, C.I.E., O.B.E., Manor House, Cothelstone, Taunton, Devon. *Editor of Journal*: Dr. H. M. Steven, 18 Alderman's Drive, Peterborough. *Business Editor*: A. N. David. *Secretary & Treasurer*: R. Angus Galloway, M.C., B.Sc., 8 Rutland Square, Edinburgh. *Auditor*: D. L. Ferguson, 25 Drumsheugh Gardens, Edinburgh. *Councillors (for 1933-4)*: W. H. Guillebaud, Chief Research Officer, Forestry Commission, London; A. D. Hopkinson, B.Sc., Divisional Officer, Forestry Commission, Chopwellwood House, co. Durham; and David Stewart, Inspector of Forestry, Ministry of Agriculture, Belfast, N.I. *Councillor (for 1933 vice Sir Alexander Rodger)*: John D. Sutherland, C.B.E., LL.D., F.R.S.E., Assistant Forestry Commissioner for Scotland, Edinburgh.

OBITUARIES

J. F. Annand, O.B.E., M.Sc.

THE late Mr. John F. Annand, Divisional Officer to the Forestry Commissioners in the north-east of Scotland, who died on 14 June 1932, was a native of Aberdeenshire. The early part of his career was spent in private forestry, and he was one of a number of young men who took the forestry course at the Royal Botanic Garden, Edinburgh, and afterwards achieved success in forestry. After holding the post of Overseer on Haystoun Estate, Peebles, for several years, Mr. Annand was appointed Lecturer in Forestry at Armstrong College, Newcastle-on-Tyne, of which he held the degree of M.Sc. When the Forestry Commission was appointed in 1919, Mr. Annand was invited to join the staff, and from the beginning held the post of Divisional Officer with head-quarters in Aberdeen. Mr. Annand was one of the original members of this Society.

George Home

SCOTTISH members would learn with regret of the death on 31 October 1932, at the early age of 42, of Mr. George Home, a District Officer of the Forestry Commission in Scotland. Mr. Home was brought up in intimate association with forestry, because his father was for many years Head Forester to His Grace the Duke of Buccleuch at Branksford in Roxburghshire. When only 18 Mr. Home was sent on the recommendation of His Grace to the Forest of Dean School, where, although two years younger than the other pupils, he took first place throughout. After being two years in Herefordshire, Mr. Home went to an appointment in Ireland. While there, he made two attempts to join the Army and was accepted on the second occasion, only to be invalided out shortly afterwards. After a further period of forestry service in Ireland, Mr. Home joined the staff of the Forestry Commission and served in the Fort Augustus district for seven years, when after an illness he was transferred to the indoor staff at head-quarters in Edinburgh. Mr. Home was a Fellow of this Society, which he joined in 1927.

H. A. Pritchard, O.B.E., F.S.I.

MR. H. A. PRITCHARD died suddenly on 6 November 1932, at the early age of 54. He was born in Cardiff, where he spent the early part of his life. Before the war he was Professor of Forestry and Estate Management at the Royal College of Agriculture, Cirencester, and during that period he was a close friend of the late Mr. Henry Elwes of Colesbourne, being associated with him in many of his forestry experiments. During the war he was a divisional officer of the Timber Supplies Department, and was largely responsible for keeping the important South Wales coal-field supplied with pitwood. On the formation of the Forestry Commission he was appointed Technical Adviser to Sir Hugh Murray, the first Assistant Commissioner for England and Wales, whom he succeeded in 1924. His work in that capacity is too well known to require record here. He was a man of outstanding energy, and he gave himself wholly to his work, the service of the department of which he was so prominent a member.

He became a Fellow of this Society in 1930.

REVIEWS

Commercial Timbers of India. Their Distribution, Supplies, Anatomical Structure, Physical and Mechanical Properties, and Uses. By R. S. PEARSON, C.I.E., F.L.S., and H. P. BROWN, Ph.D. Government of India, Central Publication Branch, Calcutta, 1932. 2 Vols. Price £5.

Review by L. CHALK

THIS is by far the most important work on timbers that has appeared for some years, and the amount of information packed between the covers of its two fat volumes is immense. Information about Indian timbers has been accumulating for a great many years from investigations carried out at the Forest Research Institute at Dehra Dun and from practical experience elsewhere, and the labour of collecting and sifting this mass of material can have been no light one. It is not surprising therefore to learn that the undertaking was inaugurated as far back as 1924, when it was officially sanctioned by the Government of India. At that time Professor Brown had completed his temporary appointment at Dehra Dun and returned to America, and in the following year Mr. Pearson returned to England and was shortly afterwards appointed Director of the Forest Products Research Laboratory at Princes Risborough. As a result the authors have had to contend with unusual difficulties—each living in a different continent, working on material obtained from yet a third, and at the same time carrying out other important duties.

The object with which the work was undertaken was to bring up to date and record all available information on the uses and qualities of various timbers and to make available, especially to forest officers, photomicrographs and descriptions of the woods so that these may be determined and identified. The authors express the hope that this information will enable forest officers and timber users to employ to greater advantage many Indian timbers of beauty and merit.

There can be no question but that there was a very real need for such a project. Even before the war Gamble's great work on Indian timbers was becoming inadequate, and the great increase in research and utilization since that time has made this even more widely felt. The position was rather unusual in that although so much research had been published on other subjects, extremely little work had been done on the actual anatomy of the timbers. The anatomical descriptions, therefore, are entirely original and represent an arduous piece of research. The sections dealing with the more practical aspects are of particular value as a critical summing up of all existing knowledge, and the part played by the author in contributing to this knowledge is not at once obvious. Actually these sections include a considerable amount of unpublished data from Mr. Pearson's own experience and observation, and a great deal of the published research referred to is also his own.

The subject-matter is arranged in botanical sequence in families, genera, and species. Preceding each family is a brief account of its chief botanical characteristics, world distribution, and importance as a source of timber. A summary of the wood anatomy of the family as a whole is also given here. The unit of description is the species, but the more important genera are preceded by summaries similar to those which are given for the families, together with macroscopic and microscopic keys to distinguish the more important species. The latter should be a very useful feature, but whether they will hold good

in all cases only experience with a large number of specimens can show. But, even if in some instances they have to be revised, they will at least have served as starting-points.

The specific descriptions include the following sections: References, Vernacular and Trade Names, Habit and Distribution, Supplies, General Characteristics of the Wood, Structure of the Wood, Mechanical Properties, Seasoning, Durability and Adaptability to Treatment, Working Qualities, and Uses—Present and Prospective. This is a formidable list. It is impossible to give an adequate account of the information contained in these sections and the headings must speak for themselves. The introduction includes a classification of the forest types and their distribution, and an account of the topography and geology of the vast territory included under the name India. The space allotted to each section naturally varies considerably in different species according to the data available and the importance of the timber. The sections dealing with the practical aspects of utilization are commendably brief and to the point, but the same cannot be said of the introductory remarks preceding each family.

The method of giving an introductory summary for each family, for most genera, and again for each species leads to considerable repetition, and much is included that is extraneous to India. A striking example of this may be found in the case of *Juglans regia*. Though this is the only species of the family Juglandaceae represented in India, there are two and a half pages about the family. Much space might also have been saved in the matter of references. These are given in full, and not by numbers, not only for the family but also for each genus and again for each species, the differences between each list being comparatively slight. The brief summary of botanical features, which is similarly repeated, might well have been omitted altogether in a work of this character, where bulk definitely detracts from its value as a practical work of reference.

No attempt is made to 'boost' particular timbers unduly, but, in the case of certain species which are worthy of more attention than they have hitherto received, it is clearly stated in what direction there is a possibility of increased utilization; and the matter, with the exceptions noted above, is strictly limited to a concise statement of facts. The underlying intention is rather to promote the more intelligent use of Indian timbers generally, a point of view which is apparent in the manner in which the common defects of each timber, such as staining, checking, and difficulties in working and seasoning, are carefully pointed out and discussed, so that the appropriate steps may be taken to counter them. Such knowledge is essential as a foundation on which to build up more extended use, and Mr. Pearson's wide experience is of great value in preserving the balance between important and relatively unimportant detail and in picking out both the possibilities and the impossibilities of each timber.

The structure of the wood is dealt with very fully by Professor Brown, and this section in many cases occupies the greater part of the specific description. Macroscopic and microscopic features are combined into a single description, subdivided according to the elements, vessels, fibres, &c. This arrangement saves space but renders it slightly more difficult to pick out the features visible with a lens. These might perhaps have been more usefully included in the section 'General Characteristics of the Wood'. Measurements are given for all the more important features such as fibre length, vessel diameter, and ray width, and for some which are not so usually recorded; and it is something of a surprise, after perusing all these details, to find that in very many cases these are based on a single specimen and rarely on more than two. The author is evidently aware of this weakness and explains in the introduction that it is due to the difficulties entailed in obtaining authentic samples of such a large number of species (320) and to the time element involved in the work. The latter is the more cogent argument of the

two as it would surely have been possible, for example, to have obtained more than a single specimen of Andaman Padauk. The immense labour involved in making measurements is beyond question, but so also is the range of variation in a species, and it might perhaps have served a more useful purpose to have limited the number of features or species measured and to have increased the accuracy of the figures. This criticism applies also to the extensive use of measurements in the microscopic keys. The key to the species of *Pterocarpus*, for example, is based entirely on measurements.

Professor Brown has evidently found the existing terminology of wood anatomy inadequate for his purpose, and some of the terms he uses are unusual. This difficulty is a real one and has been receiving considerable attention among wood anatomists during the last year or two, and it may be of interest to mention one or two of the innovations. For example, the basis on which the fibres are classified appears to be their adaptation for mechanical functions, for which purpose the relative thickness of wall and lumen is used in preference to pitting. Thus a 'libriform' fibre implies thickness of wall but not necessarily simple pitting. 'Fibre tracheid' is retained for the type of cell with a wide lumen and bordered pits. The distinction between this and a libriform fibre with bordered pits is rather vague and leaves a large group of intermediate types which are described as 'semi-libriform to non-libriform', meaning apparently only that the fibres are moderately thick-walled. The types of parenchyma, on the other hand, are clearly defined and it is always evident what is meant in the descriptions. There are also a few phrases such as 'dissepiments at the articulations' and 'parenchyma punctate' which even the experienced wood anatomist will need to look up in the glossary which is provided at the end (in the latter case he will not be much enlightened). These are, however, minor points, and it is inevitable in a work of this magnitude that there should be room for criticism, but this must not be allowed to obscure the fact that the wood descriptions represent a great piece of work.

Professor Brown has already a reputation for fine photomicrographic work, and the illustrations in this production are as excellent as one would expect. Each species has a low-power 'negative' photograph of the cross-section and a high-power 'positive' of the same section. Some will doubtless wish that a tangential section had been included in place of one of these. The negative method of photography does not lend itself very well to the conifers as it makes the summer wood appear light and the spring wood dark, and thus gives a misleading impression. Below each low-power photograph there is an outline map of India showing the distribution of the species. This is a most useful adjunct for those who are not very familiar with Indian geography.

The printing of the volumes has been done at the University Press, Oxford, and has been admirably carried out; and the price does not appear to be at all excessive for a work of this size and character.

The authors are to be congratulated on the production of a work of very great importance, and the Government of India on both its foresight in encouraging such a project and on its selection of Mr. Pearson and Dr. Brown to undertake it.

British Beechwoods. By A. S. WATT and A. G. TANSLEY. Reprint from *Rübel, Die Buchenwälder Europas*, a reproduction of all the papers relating to the Beech read at the International Botanical Congress, at Cambridge, 1930.

Review by R. BOURNE

WHILE the possibility that the beech is not native in Britain is touched upon, the suggestion is made that it may in time establish itself as the principal forest dominant, and form the climatic climax forest far beyond its apparently natural limit at

the present day. Stress is laid on the fact that there is no climatic tension zone between the oak of the midlands or the west and the 'natural' beech of the more southerly or easterly counties of England. Evidence is also adduced to show that, from the nature of the climates prevailing, the northern latitudinal limits for beech certainly lie outside the country. The altitudinal limits are referred to as undetermined, but the peculiar wind-resistant properties of the species should permit of it reaching considerable elevations, and withstanding degrees of exposure which would check the invasion of all but one or two trees. Figures are also given which purport to show that there are very few areas where the beech cannot set fertile seeds, though intermittently as in southern England, where good mast years only follow years of low rainfall. But the apparent sensitiveness of beech to early and late frosts, both as a seed-bearer and as a seedling, is perhaps insufficiently brought out, since the regular occurrence of these frosts in the low-lying areas probably contributes in no small degree to the 'Striking fact that all the three areas of southern beech described . . . are based on limestone soils, no natural beechwood occurring on adjoining clays and only a little on sands'. Though it is pointed out that the beech, here as elsewhere, is not naturally limited to calcareous soils and can even form a climax forest on podsols, no distinction is made between the loams and sands of the plateaux or low hills and those of the plains or valleys, on which latter sites the beech is often naturally replaced by the hornbeam. The statement that no natural beechwood occurs on 'clays and only a little on sands' is also misleading. In favourable situations the beech has the power of supplanting the oak, and in many localities in the southern counties has formed climax forest on true clay soils. Moreover, there are numerous woodland areas, on both sands and clays, where the beech is in process of establishing itself as the principal forest dominant. In some cases forest treatment is accelerating and in others retarding progress towards climax beechwood.

In the description of beechwood soil types, four main groups are recognized: 'I. Beechwoods on chalk; II. Beechwoods on the non-calcareous soils of the Chalk plateau; III. Heath Beechwoods on acidic gravels, sandstones, &c.; and IV. "Herbaceous" Beechwoods (Scottish) on soils derived from Old Red Sandstone (Devonian).' The profiles of selected soils in each group are described and data are given for some samples of 'Loss on ignition' and pH in the surface-layers. In a few cases a comparison is also made of the above statistics with figures obtained on similar soils stocked with ash and oak. The power of beechwood, under present climatic conditions, to increase the *natural* acidity of soils by the production of raw humus is thus demonstrated. That this is true of many beechwoods in this country may be accepted, but some of the deductions made from this fact are hardly justified. For instance, with reference to the Heath Beechwoods on the southern sands, it is argued: 'Similar soils in Denmark show a retrogressive vegetation due to soil degeneration under continuous beechwood canopy. A similar process of soil degeneration occurs here, and it is probable that its rate would be faster because of the more "Atlantic" climate, so that the degeneration would be marked during the life of a single generation of trees. From this we may infer that, on the poorer sands at any rate, a mature beechwood could not regenerate *in situ*, and that though beech colonization may be progressive on the sands as a whole, the mature wood cannot perpetuate itself after continuous cover has been established, since it rapidly brings about conditions prohibitive to its own regeneration. If this conclusion is sound no beechwood on these sands can be older than the period of life of the oldest trees. Even the brown earths of the chalk plateaux show evidence of the same soil degradation under beech canopy—a phenomenon apparently not recorded from central and southern Germany.' With regard to the last statement there is unquestionable evidence of

recognizable podsol profiles being produced by beechwoods in a comparatively short space of time on such acid 'drifts' as plateau gravel or brick-earth; but there is also ample proof from similar sites, which have definitely been under beechwood for several centuries, that further development of these profiles is strictly limited *under the climatic conditions prevailing*. For the climate, and in consideration of the stability of the present relief, these soils are relatively mature. Beechwood may be accepted as the climax forest. But the same is almost certainly true of many of the other acid sands in the southern districts. In these regions beechwood is apparently unstable only on pronounced podsol soils, which according to geological evidence in many cases must have been developed in prehistoric times, presumably under different climatic conditions and vegetation. Only certain vegetative communities, such as birchwood, can now naturally improve these soils, though it is possible that open woodland of oak and beech may effect some amelioration. Closed beechwood certainly reduces the soil to its previous condition, with the result that retrogressive vegetation appears.

With regard to growth form and yield of beechwood on the different soils, some statistics are tabulated to show that the worst growth is coincident with the extremes of soil, either the dry calcareous soils of the chalk slopes or the very acid podsol soils. The range of height growth in mature beech crops is given as 60–110 feet, and it is stated that 'in high forest the age of the beech in Britain does not greatly exceed 150 years'. The possibility of there being distinct races of beech is mentioned, but it is pointed out that the artificial origin of many woods, ignorance as to the sources of seed, and the selection method of working, render research into this question difficult. Apparently 'only smooth barked trees have been seen on the South Downs, but on the Chiltern and Cotswold plateaux smooth and rough-barked stems are generally found on good and poor soils respectively'. Thus, if seed for planting is sought for in this country, the latter localities should be avoided.

In the description of the ground vegetation associated with different types of climax beechwood, lists of species are given, as recorded on selected soils of the four main soil groups. The lists for the Southern Heath beechwoods are compiled from one or two examples only and are therefore not complete. The lists for the Northern Heath and Herbaceous beechwoods have been made in crops of artificial origin and are, therefore, not to be taken as characteristic of climax types. Biological spectra for all species, and for species with high constancy and for high average frequency, have been prepared from these lists to emphasize the affinities and differences between the several types. Taking the beechwoods as a whole the associated flora may be said to be 'rich', but relatively it is poor on the acid soils. As is to be expected, the spectra demonstrate that the soil is a very reasonable basis on which to found a classification of the field layer, but without further data, recorded separately for each distinct soil type and covering the full range of beechwood soils, no detailed classification could be attempted. Whether, under such a classification, the ground vegetation would suffice for the mapping of climax types is not discussed. Nor is reference made to the great difference between the winter, spring, and summer aspects either on paper or in the field. But in the reviewer's personal experience the early spring aspect is the easiest to read and, if due consideration is given to the historical origin of the wood, the state of the canopy, the topographical position, and the condition of the surface soil, the ground layer may be usefully employed in distinguishing the limits of the several climax types.

The principal seral stages in natural succession from grassland or heath to beechwood are shortly described for certain soil types. For instance, the generalized succession is said to be: On Chalk soils: Grassland–Chalk Scrub– $\pm$ Ashwood–Beechwood; on the

brown earths of the plateau: Grassland-Scrub-Ash-Oakwood or Oakwood-Beechwood; and on podsolized sands and gravels: Heath-Birchwood-Oakwood-Beechwood. It is pointed out that 'owing to biotic disturbance the full succession is not easily traced in its entirety', but it should have been added that even in nature these stages are generally telescoped. That is to say, the invasion of oak on a heath does not await the complete establishment of a birchwood, nor does the appearance of beech depend upon the presence of an oakwood. Moreover, an intermediate stage may be locally missed out altogether. For these reasons the mapping of climax type limits, both in the earlier and later stages of succession, is generally based on a direct survey of the soil. Nevertheless, the composition of the ground vegetation and the mixture of dominants may have indicator values, which can be utilized to facilitate the soil survey.

Other problems of silviculture and management are briefly discussed at intervals under such headings as: regeneration, accompanying trees, exploitation, grazing and fire, and parasites. Though the point is not emphasized, indications are given of the varying nature of many of these problems according to the climax type. Past treatment in general, both clear-felling and selection felling, is rightly criticized on the ground that due consideration has rarely been given to seed years, the state of the crop, and the climax type. A few constructive suggestions are made, but the real problems of future treatment are not envisaged. In this review it would be out of place to discuss them, and the reader with a knowledge of beechwoods must be left to think the matter out for himself. The authors have provided plenty of food for thought.

Studies on Tree Roots. Forestry Commission Bulletin, No. 13. H.M. Stationery Office, London, 1932. Price 2s.

Review by the EDITOR

ABOUT ten years ago it was considered desirable to institute a special study of the mycorrhiza of trees, particularly under Scottish peat conditions. Dr. E. V. Laing began this work under the supervision of Dr. (now Professor) Borthwick, and this bulletin presents the results of the investigation. During the past decade increasing attention has been paid to the study of root systems in general and mycorrhiza in particular. A series of continental papers on root-systems was reviewed in vol. iii, No. 1, of this journal, while Melin's outstanding work on tree mycorrhiza was dealt with in vol. i by Dr. Laing. Further, in 1927 Dr. M. C. Rayner published a volume on mycorrhiza generally, discussing the literature up to that time. In spite of this period of interest in root-development, our knowledge is still very incomplete, and this bulletin is therefore very welcome.

The bulletin opens with a brief general account of the structure of the root of a conifer. The first major section deals with 'The Mycorrhiza of Conifers', under structure, the fungi which form mycorrhiza, soil conditions influencing the occurrence and distribution of mycorrhiza, and the relation of mycorrhiza to the tree. A general account of the subject of each subsection is presented, and the literature freely drawn upon. Even without a background of previous knowledge, therefore, the reader gets a general picture of the status of mycorrhiza. The mycorrhiza of most of the conifers commonly grown in this country is discussed; two points of interest are the adding of a semi-endotropic class in *Larix* and *Tsuga* to the usual two classes, ectotropic and endotropic, and the record of an eel-worm disease of mycorrhiza on Douglas fir. The author has been unable to extend appreciably the knowledge of the species of fungi forming mycorrhiza. Data on Sitka spruce to add to Melin's list for other species would

have been of interest. In connexion with the rôle of soil in mycorrhiza formation, it is noted that the mycorrhiza-forming fungi may be present, but not form mycorrhiza on the trees. Stress is laid on the importance of aeration in enabling mycorrhiza to be formed, and oxidizing substances such as magnesium carbonate may be helpful. In the subsection on the relation of mycorrhiza to the tree, Dr. Laing states the pros and cons for considering mycorrhiza beneficial or harmful, but is very cautious in stating any conclusion. The evidence is admittedly contradictory, but we feel certain that weight would have been attached to an opinion expressed by the author after his prolonged and intensive research.

The second major section of the bulletin deals with 'Trees Studies on Peat'. In the first subsection the form and development of tree roots is discussed. The reviewer studied this subject at Inverliever in 1923, and the author confirms and amplifies the conclusions there made and outlined in vol. i of this journal. The surface rooting habit, the rôle of the adventitious system, whorls of adventitious roots in peats actively growing, and the influence of the surface peat and its plant origin are confirmed. The second subsection deals with the leaf and stem structure of coniferous trees in 'check'. Various structural characteristics of such trees are described and the effect of low temperature, intense light, and unbalanced metabolism discussed.

Four short sections of considerable interest then follow: mineral requirements of conifer seedlings with special reference to root-development, in which experiments on the comparative response of Norway and Sitka spruces to the absence of various ions in water culture are described; the periodicity of root and shoot growth and relation of weight of root to weight of shoot; seasonal variations in the starch stores; and periodicity in the growth of mycorrhiza.

The bulletin concludes with a discussion of the relation of the research to practical forestry. There are 17 plates and a bibliography.

Dr. Laing is to be heartily congratulated on a publication which breaks new ground in this country. The subject is one of special difficulty and, if no outstanding new conclusions have emerged, a considerable amount of valuable data has been accumulated, some of which may prove of distinct practical value.

Forsøk med vestamerikanske træslog. By OSKAR HAGEM. Meddelelse No. 12. Vestlandets Forstlige Forsøksstation, 1931.¹

Review by W. H. GUILLEBAUD

THE west coast of Norway, with its steep bare mountain slopes and high rainfall, presents an afforestation problem not dissimilar in many respects to that of the west of Scotland, so it is scarcely surprising that the attention of Norwegian foresters should have been directed to the possibility of establishing some of the Pacific Coast conifers which appear so well adapted to our Atlantic seaboard. The higher latitude of Norway, however, necessarily results in appreciably different climatic conditions from ours, i.e. in more severe cold in winter, in cooler summers, shorter growing-seasons, and so on. Certain early investigations showed that ordinary commercial seed of such species as Sitka spruce and Douglas fir could not be used in Norway owing to the severity of the climate, but this failure only encouraged the Vestland Forest Research Station to pursue its inquiries a further stage. It is a commonplace, when dealing with the introduction of exotic species of trees, that the native climate of the tree to be introduced

¹ A short notice of this work appeared in *Forestry*, vi, No. 1, but in view of its interest a fuller review is now published.

should resemble closely that of the locality for which it is intended. Unfortunately, in climate we are not dealing with a simple thing but with so complex an association of factors that we are still in considerable doubt as to how to make the comparison between the climate of any two separate localities. The work under review forms a most interesting contribution to this problem. The work is written in Norwegian, but there is a very full summary in German.

In the first chapter the author discusses the general principles to be followed, and comes to the conclusion that the mean temperature of the four months June to September (summer heat, so called) forms one useful index for comparative purposes. He adds the caution, however, that the general character of the climates to be compared must also be taken into account. The summer heat index may be an unreliable guide if applied to a continental as contrasted with an oceanic climate, because the variations both above and below the mean are so much greater in the continental type of climate.

A second guide is the length of the growing period, a point of great importance in relation to the occurrence of late and early frosts. For Norway Hagem takes as the start of the growing period the date on which the leaves of the birch begin to emerge from the buds (a very interesting use of a phenological observation); according to data collected by himself this occurs when the mean day temperature reaches 7.5°C . The end of the growing period is less easily fixed, but Hagem assumes it as the date on which the mean daily temperature again falls to 7.5°C . The initial and final dates can be read off a local mean temperature curve if this is based on the mean temperatures of the individual months.

Thirdly, the degree of winter cold has to be considered; in this connexion the minimum temperatures and number of frost days are of importance. Finally, the amount and especially the distribution of rainfall must be brought into relation.

In Chapters II and III the author describes in detail the rainfall and temperature conditions of western Norway and of the Pacific Coast of North America from Cape Flattery in British Columbia, latitude $48^{\circ} 25'$, to Mount Fairweather in Alaska, latitude $58^{\circ} 50'$. The comparison of Vancouver Island with Bergen in the south-west of Norway shows that as regards 'summer heat' Vancouver approaches closely the value for Bergen, but that the 7.5°C . growing period is far longer at Vancouver, 224–200 days as compared with only 169 days at Bergen. Further, the winter temperatures are lower at Bergen. It is necessary to go considerably farther north—to the neighbourhood of Prince Rupert and Port Simpson (latitude 54°)—to find a climate approaching to that of the outer coast of south-west Norway. Farther north from Bergen the climate of the west coast of Norway becomes appreciably colder, but Hagem has found in Juneau in South Alaska (lat. 58°) a climate almost identical with a large stretch of the Norwegian coast from Trondhjem Fjord southwards. The summer heat at Juneau is 12.3°C ., the same as in the neighbourhood of Möre in west Norway. The 7.5°C . growing period is 153 days at Juneau (5 May to 4 October) and 155 days (5 May to 6 October) in the Möre Fjords. The only substantial difference as regards temperature is the lower mean temperature occurring during the winter months at Juneau. Rainfall conditions are also very similar in the two areas.

Between the years 1915 and 1928 quantities of seed of the principal north-west Pacific Coast conifers were collected from known localities and sown in the nursery of Söfteland, 12 miles south of Bergen. The author explains that owing to the shut-in situation of the nursery, which lies in a deep hollow, far lower minimum temperatures occur than its proximity to the relatively mild climate of Bergen would suggest. The effect has been to expose all the sowings to relatively very severe conditions both as

regards winter frosts and frosts during the actual growing period. The procedure has been briefly as follows: Seed was sown in the nursery and protected in the usual way, the numbers of plants damaged or killed by frost were recorded and survivors planted out in blocks along the length of the west coast of Norway from Trondhjem Fjord southwards. The paper under review deals only with the results in the nursery stage; the plantations will presumably form the subject of a future report.

The following species were sown: *Picea sitchensis*, *Tsuga heterophylla*, *Thuja plicata*, *Pseudotsuga taxifolia*, *Cupressus nootkatensis*, *Abies amabilis*, and one or two other species of *Abies* and other genera. Of these trees Sitka spruce is regarded as much the most important and seed of 49 separate origins were sown, the localities ranging from Washington and Oregon to Juneau, Kitimat, and Kruzow Island in latitudes 57° and 58° in Southern Alaska.

The conditions in Söfteland Nursery proved altogether too severe for any of the American seed or for the seed from the southern regions of British Columbia. In unfavourable seasons all the plants were killed the first year, in milder seasons a proportion of the plants would survive but only to be killed out in the second or third year. The early autumn frosts, destroying the unripened shoots, are believed to have been mainly responsible for the failures. Seed from the 54^{th} degree of latitude, from the neighbourhood of Prince Rupert, represent the most southerly origin to give even passably good results. The percentage of plants frozen was 20 per cent. in the first year, in the second year 30 per cent. of the remainder were frosted but mostly only to a slight degree. It will be recalled that the climatic features of Prince Rupert were virtually identical with those of Bergen, so that a rather more favourable result might have been expected. The discrepancy is probably due to the peculiar situation of the nursery, where frosts normally recur earlier in September than at Bergen, while the 7.5°C . growing period is 15 days shorter. Hagem's conclusion is that seed from about 54° latitude should be frost-hardy in the neighbourhood of Bergen but would need to be raised in a more favourable nursery than that of Söfteland.

The fate of the four samples collected in the Queen Charlotte Islands is perhaps of special interest to British foresters because from those islands comes most of the seed now being used for afforestation in this country. None of the four lots of seed proved hardy in the nursery, in marked contrast to the Prince Rupert seed coming from almost the same latitude but on the mainland. Hagem ascribes the difference to the insular climate of the Queen Charlottes, and in particular to their relatively mild winters. The Alaskan seed proved definitely more hardy than that from the north of British Columbia. Seed from 55° to 57° latitude produced plants which in the first three years showed only 10.5, 15, and 0 per cent. frosted plants as compared with 17.5 and 30 per cent. (first two years only) in the case of the Prince Rupert seed. Seed from farther north still—from Juneau and Hooniah—was still more hardy, and the frost damage was so slight that the success of plants from this seed as far as the nursery stage is concerned could be regarded as assured.

The experience with *Tsuga heterophylla* has been identical with that of Sitka spruce. Seed from farther south than Prince Rupert in British Columbia was useless for Norwegian conditions. Seed from southern Alaska yielded hardy plants of excellent quality.

Of the three forms of Douglas fir it is interesting to note the author's opinion that only the green coastal variety is of importance for coast conditions in Norway. He remarks that the blue form grows even slower than their native spruce and so has nothing to recommend it. The experiments with different seed origin of the Green Douglas do not appear, however, to have led as yet to the discovery of a strain hardy under the severe conditions of Söfteland Nursery. The most northerly origin used was

from Bella Coola, which is some 75 miles inland from the coast and on about the same latitude as the southern end of the Queen Charlotte Islands. Twelve lots of seed from this district were sown between 1917 and 1921. In some cases a proportion of the plants survived the first two years and thus showed themselves hardier than the more southerly origins, which were wiped out in the first winter. Nevertheless, none of the plants survived the onset of an unusually severe winter. The possibility still remains that, in a more favourable nursery, Douglas fir from the latitude of Bella Coola might be raised successfully for use in west Norway. One sample of the Fraser River variety which came from Mount Ida Forest near Salmon Arm proved quite hardy in the nursery, and Hagem suggests that it might be a suitable provenance for use in the east of Norway.

Only three lots of seed of Nootka cypress were sown, from Bella Bella, lat. 52° , from Prince Rupert, lat. 54° , and from Chicagoff Island in Alaska, lat. 58° . Plants from the first two lots were severely damaged by frost, but the Alaskan seed proved hardy and yielded excellent transplants for putting out in the forest plots.

It is much to be regretted that the present report covers only the nursery stages of the experiment, for inclusion of even preliminary data from the field plots would have added greatly to the interest of the report. To say this is not to detract in any way from the importance of Hagem's work, which is one of the most useful contributions to the provenance question which has yet been made. The introduction of exotic species is to the fore in almost every land where forestry is practised to-day, but few countries have tackled the problem in the scientific yet practical spirit so clearly evidenced in the paper under review.

Twelfth Annual Report of the Forestry Commissioners for the year ending September 30th, 1931. H.M. Stationery Office. Price 9d. Postage extra.

Review by B. C. ADKIN

THE Forestry Commission has not escaped the blast of the economic crisis, and this report begins with an account of the sequence of events and discussions leading to the final settlement under which the Commissioners were left with much reduced grants. This sudden check coming near the auspicious beginning of the second decade was very disappointing, but under the circumstances the Commissioners probably did well not to fare worse. The grants have been roughly halved, but the Commissioners state that they can maintain the essential elements of their forest policy, even though the scale is smaller than they would desire on purely technical grounds, and will be in a position to resume work on an adequate scale when times become more propitious. The Government has undertaken to provide annually for the next five years the sum of £450,000, which, with working receipts, will allow rather less than £600,000 per annum to be spent on forestry operations. In consideration of this the Commissioners propose to carry out in the next five years the following operations:

- (1) Maintain a planting programme of upwards of 20,000 acres per annum.
- (2) Acquire sufficient plantable land to keep intact the reserve of land which is required for maintaining the planting programme.
- (3) Provide sufficient forest workers' holdings (numbering, perhaps, 15 or 20 per annum) for working the forests efficiently, and also repair and maintain such holdings as are necessary for the utilization of the non-plantable land.
- (4) Provide grants for planting on the same scale as during the last three years.
- (5) Maintain intact their research activities, and make suitable provision for forestry education and other ancillary activities.'

The report then goes on to state shortly the result of a recent inquiry into the position of forestry on private estates. A reference was submitted to the Consultative Committees of England, Scotland, and Wales respectively inquiring what further effective action the Commissioners might take to promote production of timber by private owners. After the three committees had considered the subject separately, their Chairman presented a joint report. This is shortly described. It seems to be a chronicle of despair which makes no suggestion as to how the Commissioners might assist more than they are already doing. The report continues: 'In the long run, therefore, the State might have to relieve the private owner of his responsibility in maintaining the woodlands of Great Britain and to take such work in hand before the woodland conditions have been dissipated, thus avoiding irreparable devastation. It would be in the national interest for the Commissioners to take over woodland areas on fair terms in cases where, after every possible encouragement and State co-operation had been offered, the owner was unable to plant.' It is not clear that this statement is not derived from the joint report of the Consultative Committees. If it were that report would be an interesting document, but it is more likely a restatement of the Commissioners' views. That very representative body of opinion, the Central Landowners' Association, appears to think otherwise.

It is recorded that Sir John Stirling Maxwell has ceased to be Chairman and also resigned his membership of the Commission, that Mr. J. H. Alpass has also resigned, and that Major S. Strang Steel and Sir Alexander Rodger have been appointed Commissioners.

The rest of the report is occupied with the usual information presented in the customary manner. During the period considerably more plantable land was acquired than in the previous year, and an inspection of the maps shows that in nearly all cases the new acquisitions were enlargements of areas already held. The area acquired was 48,858 acres, out of a proposed 60,000 acres. The area actually planted, however, was 630 acres in excess of the 25,000 acres proposed, and of these 25,630 acres 23,683 were placed under conifers. Some sixty million trees were planted, of which 37 per cent. were Scots and Corsican pines, 32 per cent. Norway and Sitka spruces, 13 per cent. European and Japanese larches, and 3 per cent. Douglas fir; the use of the last named has been declining for the past few years. Financial assistance to local authorities and private owners was slightly less than in the previous year. The damage by fire was much the same as in 1930—about £2,000 in value; the exceptionally high figures for 1929 were evidently abnormal. As usual, railway engines were responsible for most of the outbreaks, with the general public a good second. A brief note on the experimental work that is being done in connexion with nursery treatment and establishing crops shows that, like the research in forest pathology, it is not only interesting but of a kind to produce useful results; and it is satisfactory to know that it will be continued. A report is to be issued giving statistics of the production of home-grown timber during 1930, and estimates of the final totals indicate that for Great Britain as a whole the production of both conifers and hardwoods was less than shown by the census of 1924. For conifers the figures are 30,890,000 cubic feet for 1924 and 26,405,000 cubic feet in 1930, and for hardwoods the corresponding figures are 25,094,000 cubic feet and 21,652,000 cubic feet. Taking the countries separately, England and Wales have increased their production of conifers and Scotland and Wales have produced more hardwoods, but these increases do not compensate for the decline in the production of conifers in Scotland and hardwoods in England.

Report of the Forest Products Research Board, 1930. H.M. Stationery Office, Adastral House, Kingsway, London, W.C. 2. Price 4s.

Review by W. L. TAYLOR

PROGRESS of the work at the Princes Risborough Research Laboratory has been well maintained; much has been attempted and results of interest to all sections of the wood-using professions and trades are being achieved. No time appears to have been lost in getting to work with the scheme of services on behalf of timbers from the Empire Overseas which was commenced under the auspices of the Empire Timbers Committee in 1929. Sections of wood structure and chemistry are now housed at the Laboratory and a separate section of physics has been established. The construction of the special house for the study of dry rot and the death-watch beetle has been completed and kilns and plant have been extended and modified.

Wood has a long and sustained record of utility in the service of mankind, a service over which empiricism has long held sway, but which the present-day expansion of scientific knowledge and the ingenuity of man is developing in directions undreamed of only a few years ago. The supplanting of timber in industry by other products seems farther away than ever before. This report brings into relief the lines on which research is being made into technical improvements calculated to prolong the life of timber in its everyday uses, and projects possibilities of new utilization and the employment of timbers new to commerce. The utilization of Empire timbers from overseas offers wide field for investigation. The properties of such timbers require to be made known before the practical problems of exploitation and transport can seriously be tackled. Tests of a considerable number of exotic timbers are recorded, and trials of Empire flooring and decorative woods are being made in the Laboratory buildings. The known difficulty of impregnating Douglas fir with preservatives has received attention; appropriate specifications for the treatment of Douglas fir sleepers have been evolved, including incising to facilitate the sufficient lateral penetration of the preservative.

A section of the report is again devoted to kiln seasoning. Regarding oak, a *caveat* is entered; it is stated that 'an important outcome of the work has been the conclusion that, in thicknesses much greater than one inch it is not in general likely to be an economic proposition to kiln-season English oak from the green without a preliminary period of air seasoning'. Preparations have been made to study the process of steam bending, and the experimental work planned is being put into operation.

Some evidence of the influence of the site factor on the quality of timber is interesting to silviculturalists. Reference is made to the disparity in mechanical strength shown between two parcels of Corsican pine from the east and south of England respectively; the heartwood of the former parcel has been found lower in lignin content and is also the weaker wood mechanically. The difference could not be explained on anatomical grounds and it is suggested that the weakness may be due to the lower lignin content.

Attention has been devoted to the composition of 'wood smoke' used in the curing of fish—an instance of the catholicity of the problems attacked. Samples of condensed smoke have been analysed qualitatively with a view to the identification of the constituents instrumental in the curing of fish. If the investigation meets with success, it may be that those fish-like smells, often also designated ancient, may become a thing of the past so far as the fish-curing industry is concerned. In consultation with other bodies, an attempt is being made to revise the specifications for building timbers. It is a thorny subject, but apparently some progress is being made in the direction of seasoning and moisture content. The work on the wood-destroying fungi has been continued

and the collection of species has grown to one hundred and thirty. The study of *Paxillus panuoides* has been completed and will be published. In the entomological section the work on *Lyctus* and the furniture beetles is still in progress and the susceptibility of timber to *Lyctus* attack has received attention. Some preliminary experiments on the use of X-rays in the detection of insect attack on wood have proved partially successful.

The report is suitably illustrated, and the work attributable to individual members of the staff is very generously acknowledged. The list of publications in the form in which it is appended is a feature which might more generally be incorporated into the annual reports of the scientific and technical departments.

FOREST PRODUCT RESEARCH LABORATORY PUBLICATIONS

Reviews by J. T. SMITH

Report on the Creosoting of Douglas Fir Sleepers. Project O, Investigation 37 A, Forest Products Research Laboratory.

THIS report was issued by the Forest Products Research Laboratory in December 1931. It relates to experiments made upon two small consignments of imported (British Columbian) Douglas fir sleepers numbering 64 and 24 respectively, taken six at a time, owing, it is stated, to the capacity of the cylinder in use. The report runs to 15 pages of typewritten matter and 10 photographs or charts. The experiments were undertaken with the object of finding a method of treating imported Douglas fir sleepers in order to obtain a satisfactory absorption and distribution of creosote. The report claims that by a method of incising (the process being carefully detailed and illustrations given of the machine which was made in the Laboratory) the minimum increase in absorption was 35 per cent., while the maximum shown is 78 per cent. After incising the process recommended is a high preliminary vacuum of 20 inches for 1 hour followed by a pressure of 170–180 lb. per sq. inch until an absorption of 8 lb. per cubic foot has been obtained. This should usually be from 3 to 6 hours. The temperature of the creosote should not be below 160° F., nor higher than 200° F., during time of treatment. The tests gave contradictory figures concerning the effect of moisture content on absorption. The main factors to be considered in the treatment of Douglas fir sleepers are apparently the temperature of the oil and the duration of the pressure period. The normal absorption specified for standard Baltic fir sleepers, viz. 9 to 10 lb., is readily attainable by the foregoing methods in Douglas fir. Full details are given in the report of side, end, and percentage penetration.

Incising is a recognized process in British Columbia and impregnation up to 18 to 20 lb. of creosote oil per cubic foot has been obtained. The method, however, has not been developed as yet in this country, and, with the prospect of the increasing use of Empire timber, it is useful to have trials with British oil in this country.

The Timber of Home-grown Scots Pine (Pinus Sylvestris L.). Department of Scientific and Industrial Research, Forest Products Research, Bulletin No. 15. Dec. 1931. H.M. Stationery Office. Price 5s.

THIS comprehensive report of research work, spread over at least six years, sets forth in seventy pages, and with the help of thirty illustrations, a considerable amount of detailed information regarding home-grown Scots pine. There are eight sectional

reports, dealing respectively with structure, seasoning, mechanical and physical properties, reaction to antiseptic treatment, response to tools and machinery, liability to insect and fungi attack, and utilization. The samples tested came from various parts of England and to a very limited extent from Scotland, all from trees of varying aspect, elevation, and soil condition, and therefore not strictly comparable. Except in the case of pit props the tests were made on small pieces and under limited conditions at the Laboratory. The report says that locality must be largely taken into consideration, and for that reason it is doubtful whether the conclusions drawn can be accepted except as an indication to growers in this country of what to avoid. The information given in regard to rate of growth is particularly important (best quality timber = 12 rings to the inch). The report claims to provide an accurate estimation of the relative value of the home-grown timber as compared with imported material from north Europe of the same botanical species. Much of the information is known to those who handle the timber, but the data presented give precision to this knowledge. As Scots pine is indigenous to Scotland but not to other parts of this country, it is disappointing that more samples were not drawn from these. It will not be accepted without further evidence that timber from the south will be stronger than timber of the same rate of growth from the north, although the Perthshire samples tested may have responded in that way. The summary concludes with a note of suggested new uses for Scots pine, and more research on these would be useful. The prominence given throughout the whole bulletin to the *slight superiority* of imported timber may discourage the production and sale of Scots pine in this country.

Home-grown Pit Props. Department of Scientific and Industrial Research, Forest Products Research, Bulletin No. 9. Feb. 1931. H.M. Stationery Office. Price 2s.

THE use of timber in mines is still (in spite of steel) one of the largest uses of timber in this country. It is natural therefore that the Forestry Commission and the Forest Products Research Department should collaborate in an extensive series of tests to determine the strength and seasoning qualities of home-grown and imported pit props. Some durability or service tests in the mines of South Wales were also made jointly and the results are set out in this report. It is indicated that the service demands upon mining timber in that coal-field are as severe if not more so than in any other mining area in Great Britain. The material was prepared and supplied by the Forestry Commission and the tests carried out by the Laboratory staff with the help of the mining officials. The bulletin is of importance for the records kept while the home-grown props were in use in the mines. Another matter of importance is the study of the actual conditions of the marketing of home-grown pit-wood and of the economic conditions involved. The present publication provides certain results, but a further step in this direction would be of great value and would be welcomed by those concerned. The Forestry Commission might with advantage draw some evidence from the war experiences in Scotland, which entirely supported the Scottish mines with home-grown pit-wood for a year or two and in addition sent appreciable quantities during the same period to England. The results in this report show that some of the samples of props sent from Scotland were above the average of all the others tested, including imported props. From the average results, however, the bulletin may not make it easier to sell home pit-wood. Some of the comparative statistics given according to species in this bulletin are misleading, e.g. 'European larch is about 10 per cent. stronger than the average

Scots pine or Douglas fir' and European larch is of about the same strength as imported spruce.

A Survey of the Damage caused by Insects to Hardwood Timbers in Great Britain. By R. C. FISHER, F. R. CANN, and F. R. PARKIN. Department of Scientific and Industrial Research, Forest Products Research, Bulletin No. 16. H.M. Stationery Office. Price 2s. 6d. net.

Review by R. N. CHRYSTAL

THIS bulletin is the second publication of the Forest Products Research Laboratory to deal with the *Lyctus* beetle problem in this country, a problem which has engaged the attention of their entomologists for the past five years. It represents a determined effort to arrive at an assessment of the present position of the problem in this country, by means of a comprehensive survey of the conditions under which timber is imported into the country, and the conditions obtaining in the timber yards and storage places throughout the country with reference to *Lyctus* attack.

The authors emphasize at the outset the extreme practical difficulties which lay in the way of making the study as thorough as they would have liked it to be. These are concisely reviewed on pages 2 and 3, and a little reflection on the matter after reading the bulletin will make it quite evident that, considering the limitations imposed, the survey which was conducted over a very wide and representative area has yielded most valuable results.

The middle portion of the bulletin (pages 3-14) provides ample data on the practical aspects of the *Lyctus* problem in relation to the importation, storage, and utilization of timber, and should be of the greatest interest to importers and manufacturers alike.

The remainder of the bulletin deals with 'Pinhole Borers', Longhorn beetles, and other insect borers of minor importance, and contains useful data and comparative descriptions of their work in contrast to that of the *Lyctus* beetles.

Two main conclusions will be drawn by any one who studies the bulletin carefully. Firstly, that those types of insect damage referred to in the latter parts of the bulletin as being caused by 'Pinhole Borers', Longhorn beetles, and the like, are, in the main, problems for the forester to deal with, to the solutions of which the importer and manufacturer can contribute little or no help of practical value except in so far as he makes himself acquainted with the types of damage caused by these insects and does not confuse it with that of *Lyctus*. Secondly, that the general condition of the *Lyctus* problem in this country is set down quite clearly by the authors in this bulletin, and they can in all probability not go very much farther until—and this is the important point—importers and manufacturers alike get together and review the whole question of timber importation, storage, and manufacture. The authors state that certain measures for preventing *Lyctus* attack are of practical application, and that it is imperative that the latter should be universal.

It is up to the timber trade now to see to it that some consideration is given to the matter, and to try to effect some change in the methods which will render impossible conditions of timber storage such as are illustrated in Fig. 8 of this bulletin.

It is much to be hoped that this publication will result in active steps being taken in this direction, and that the Laboratory will reap the reward which from the nature of the work already done it fully deserves.

SOME RECENT PUBLICATIONS ON TIMBER INSECTS

By RONALD C. FISHER

THE damage caused by insects to timber has recently been receiving increased attention by entomologists in many parts of the world. The problems presented by the insects responsible have assumed serious proportions and indicate how little is really known of the conditions in timber which are suitable for the development of the various groups of wood borers. Research is in progress into these problems, and it is hoped this will lead to improved methods of prevention and control. In the meantime, there have recently appeared a number of publications which summarize existing knowledge and describe the steps that can be taken by timber users and the public in general to prevent needless losses. The following publications are of special interest:

1. *Furniture Beetles*. British Museum Pamphlet, Economic Series, No. 11. By Dr. C. J. GAHAN. Third edition. July 1932. Price 6d.

THE third edition of this useful pamphlet has been revised and enlarged by Mr. F. Laing, M.A., B.Sc., and provides a general account of the Anobiid and Lyctid beetles responsible for damage to timber and furniture in Great Britain. The publication is divided into three sections: general information on the insects concerned, including short notes on their natural enemies (parasites and predators); an account of the life-history of the species; and methods of prevention and control. It is to be regretted that opportunity was not taken in revising this useful pamphlet to separate more completely the two groups of insects described, namely the true furniture beetles, family Anobiidae, and the powder-post beetles, family Lyctidae. The *Lyctus* beetles are, strictly speaking, not furniture beetles; their mode of nutrition and the conditions in timber necessary for their attack differ markedly from those associated with the true furniture beetles (*Anobium*, *Xestobium*, *Ptilinus*, *Ernobius*), points of difference which are brought out in the pamphlet. From the point of view of the timber user, clear distinction between the groups of insects likely to prove of economic importance to him is very desirable. This publication may lose some of its value to the wood-using industries by including under the one title 'Furniture Beetles' insects which, on the one hand, are of first importance to the timber merchant and manufacturer and insects which, on the other hand, are seldom, if ever, found on their premises.

The pamphlet is excellently illustrated and contains a number of plates additional to those which have appeared in earlier editions. The figures of the four species of *Lyctus* mentioned (*L. brunneus*, *L. linearis*, *L. parallelopedus*, *L. planicollis*) are especially good, and clearly show the characteristic differences of each. A useful new paragraph in this edition describes the use of fillers for closing up exit holes in attacked furniture. Another additional section deals shortly with powder-post beetles in timber yards, but the possibility of putting into practice several of the methods of control advocated, for example, spraying or dipping of stacks of timber, are open to question on economic and practical grounds.

The publication fills a need in providing a general up-to-date account of the damage caused by the more important insect pests of seasoned timber in Great Britain and should prove of special interest to the householder. As in earlier editions, no references are quoted, an omission which will be greatly missed by those wishing to refer to papers dealing in greater detail with the groups of insects concerned.

2. *Wood Borers in Australia, Part I. Lyctus, or the Powder-post Beetle.* Commonwealth of Australia. Council for Scientific and Industrial Research, Division of Forest Products, Trade Circular No. 6. 1931.

THIS useful pamphlet, which describes in a clear, concise manner the importance of *Lyctus* powder-post beetles and outlines methods of their control, has been prepared to assist the timber industries and large-scale users of timber, as well as the householder, in Australia. It forms the first of a series of trade circulars dealing with the various types of wood borers in Australian timbers. Based as it is on a careful study of all available literature, the leaflet is an excellent publication and gives an admirable summary of the *Lyctus* problems, applicable not only to conditions in Australia but also in other countries where these insects cause serious losses.

A valuable section of the pamphlet sets forth in tabular form the distinguishing features by which the attack of powder-post beetles, pin-hole borers, and furniture beetles can be easily recognized. The Division of Forest Products is to be congratulated on the production of a publication which will materially assist not only in controlling the ravages caused by *Lyctus* in Australia but also in preventing the occurrence of these insects in timbers exported from that country and for which it is hoped to find markets in Great Britain and other parts of the Empire.

3. (a) *La Piqûre du Bois de Chêne mis en Œuvre, Causes, Moyens de Protection.* Commission d'études des ennemis des arbres, des bois abattus et des bois mis en œuvre. Bulletin No. 8. 1931.

(b) *La Vermoulure des Meubles et Menuiseries.* Commission d'études des ennemis des arbres, des bois abattus et des bois mis en œuvre. Bulletin No. 14. 1932.

THE above leaflets have recently been published by the French Ministry of Agriculture and summarize very briefly methods of control in operation in France for dealing with *Lyctid* and *Anobiid* beetles. It is of special interest to note that in France ringing of oak-trees in the spring before felling during the following winter is advocated as a means of preventing *Lyctus* attack in timber after conversion. The object of this is to ensure that the cell contents will no longer be suitable as food material for the larvae. Wilson (*Nature*, vol. cxxx, No. 3270, pp. 22-3, July 1932) has recently shown in England that starch apparently forms the food of *Lyctus* larvae, and it is to ensure that all the starch will have disappeared from the timber before felling and conversion that ringing of trees is advocated by the French authorities. This method of control may present serious practical difficulties but, where possible, merits special consideration.

The Natural Woodlands of Britain and Ireland. By M. L. ANDERSON, D.Sc. (Edin.). Pp. 32. Holywell Press, 1932.

Review by W. L. TAYLOR

THE author is to be congratulated on his study of the climax forest types of Great Britain and Ireland. The subject is of deep interest and is a very complicated and difficult one. The publication, breaking almost virgin ground and compiled by a forester for foresters, is warmly to be welcomed.

The first part of the booklet contains an able classification of the natural woodland

types into fifteen main communities, only one of which, the beechwood association, has yet been studied at all intensively. The list covers the principal types of woodland but omits the primitive oak-hornbeam association of south-eastern England, which would seem also to merit inclusion.

The fifteen forest communities chosen are described in outline, and the survey is completed by reference to the modern, and marked, tendency towards the suppression of ancient types of natural woodland, mainly broadleaved, by conifer species which have been introduced from abroad. In his table of the species in use in the artificial regeneration of natural woodlands the author shows a predilection for Douglas fir which is hardly in accordance with the experience of the past decade; his advocacy of Silver firs, however, is qualified in the case of *Abies pectinata*, now almost an impossible tree to raise successfully to maturity in Britain.

In the second part of the booklet a classification of waste-land types is the aim. This again is a most complicated subject; the influence of soil fertility, soil aeration, moisture content, and climate being interrelated in combinations which merge into one another in degrees only perceptible after close study in the light of a wide experience. The author makes the term 'waste land' mean any land available for the planting, though the term is not perhaps the happiest one.

Seventeen plant community types are described in conjunction with five arbitrarily chosen degrees of soil fertility, and a paragraph is devoted to the anomalous plant communities. Stress is laid upon the inadvisability of attaching too great a significance to the wrong species, and in this connexion the author's complete condemnation of bracken as an indicator seems to be justified only in the broadest possible sense so far as the British Islands are concerned. So to a less extent is the placing of *Calluna vulgaris* and *Molinia caerulea* in a like category. It is now established well enough for the purposes of practical forestry that the former indicates the prescription of *Pinus silvatica* and others of the pine family, and the latter (if turfed) is especially adapted to the spruces.

It is agreed that bracken often masks one of several common plant communities, but its presence is at least a valuable local indication of an open and aerated condition of the surface soil, a condition which is so essential to the well-being of most species of tree that it is half the battle in establishing an artificial wood. Bracken is also a useful delineator of frost zones. The fact that bracken may occur on deep fibrous peat is adduced to its discredit, but such bracken colonies are always restricted in area and importance; moreover they are generally found in the vicinity of rock outcrop or boulders which have afforded the degree of aeration necessary to give the bracken a start.

It is noticeable that the author is conservative in his advocacy of turf-planting. Unless the forester is willing to face the long, depressing, and quite unnecessary period of 'check', this method is essential with the spruces and Japanese larch on the very extensive, wet, and badly aerated sites in the north and west of these Islands, and is especially advisable when dealing with the *Molinia* communities.

At the same time it is but fair to say that the author freely admits that there is much work still to be done in the field covered by the second part of this most interesting paper, which, as it stands, may prove conducive to mistakes unless applied with caution. Certainly this section is meant only for those whose knowledge of plant ecology in its application to forestry is well above the average. This booklet will doubtless be widely read, and will prove provocative of further researches into the important and highly interesting subjects involved in the classification of plant communities as an aid to foresters in the choice of tree species.

A list of references would have been helpful.

Conifers in Cultivation. The Royal Horticultural Society, London, 1932.
Price 21s.

Review by the EDITOR

THIS volume is the report of the Conifer Conference held under the auspices of the Royal Horticultural Society in November 1931. The previous conference held on this subject by the Society was in 1891, and the intervening period has seen a great advance in the cultivation of conifers both for ornamental and economic purposes.

The first subject dealt with was nomenclature. The rules laid down by the Vienna Congress of Botanists in 1905 have not been rigidly followed in this country because of the hope that a list of *nomina specifica conservanda* would be agreed, thus enabling names long used to be retained. The Cambridge conference of 1930 removed that hope, hence it will be best to adopt the names dictated by the Vienna rules, in the hope that some measure of stability will now ensue. Mr. Dallimore gives a list of conifers, cultivated out of doors in this country, with the correct names and synonyms.

The Society endeavoured to make the contributions to the conference as comprehensive as possible, and the titles of the papers cover most of the field. On reading the papers, however, one gets the impression that the authors felt that in the time available they could not do justice to their subjects: some endeavoured to give a general bird's-eye view, others dealt with aspects which they knew most intimately. If the papers are consequently uneven in comprehensiveness, a great mass of important and interesting information and views have been brought together. The following are some of the papers of greatest interest to foresters:

'The Influence of Exotic Conifers on Silviculture in the British Isles', by Sir John Stirling-Maxwell. This paper should be read by all British foresters because it presents in concise form the history of exotic conifers in this country. As a rule, land-owners have experimented with exotic trees under favourable conditions, but Sir John Stirling-Maxwell has directed his efforts to establishment under really difficult conditions, and has thus rendered important service both to forestry and the nation.

'Random Notes on Diseases of Conifers', by Professor A. W. Borthwick. The author deals with diseases recorded and described in the Royal Scottish Arboricultural Society's *Transactions*.

'Propagation of Conifers', by L. B. Stewart. Mr. Stewart does not deal with the great mass of work which has been done in all parts of the world in connexion with commercial forestry. The principal interest of the paper is the description of the author's methods of striking cuttings.

'The History of Conifers in Scotland and their discovery by Scotsmen', by F. R. S. Balfour. This paper contains much interesting historical material.

'The Economic Value of the Coniferae', by W. Dallimore. The scope of this subject is clearly beyond the limits of a short paper, but Mr. Dallimore has succeeded in bringing together an imposing array of information.

'The Conifers of Kenya', by H. M. Gardner, and 'Exotic Conifers in South Africa', by C. E. Legat.

A considerable part of the book is taken up with statistical data of conifers growing in different parts of the country.

There are many beautiful photographs of conifers, and the volume is one which all foresters who can afford it should acquire.

The Trees of Yosemite. By MARY CURRY TRESIDDER, with 34 Linoleum Block Prints by DELLA TAYLOR HOSS. Stanford University Press, 1932. Price 11s. 6d.

Review by the EDITOR

THERE is a vogue in America for popular books about trees which has not yet reached this side of the Atlantic. This book is chiefly notable as a work of art. The margins are wide, the type striking, and the illustrations of special interest. In recent years, linoleum block prints have been used more and more for illustration, and this book presents an opportunity of judging their suitability for semi-scientific illustration. The result is pleasing, and the pictures of cones and trees definitely convey a faithful impression of their subjects, although the medium does not enable the degree of precision necessary for scientific illustration to be attained.

This book will appeal to all who appreciate fine printing and illustration, and particularly if they are foresters also.

NOTICES

Die Geschichtliche Methode in der Forstwirtschaft. By Dr. H. MARTIN, Berlin, Julius Springer, 1932. R.M. 13.50.

THE veteran Dr. Martin has looked back over the sixty-five years since he entered his profession, and beyond, and has written this interesting history of German forestry.

The book is divided into two parts, silviculture and forest management. The first will be of principal interest to British foresters. Following an introductory section he deals with the four principal German trees: beech, oak, pine, and spruce. The occurrence of each in natural forest, pure and mixed stands, and so on is discussed. Then follow sections on silvicultural systems, broadly divided, methods of regeneration, and thinning. As befits a man of 80 years he takes a mature and balanced view. While alive to the dangers of pure even-aged stands he does not swing to the other extreme, the naturalistic *Dauerwald* school. He lays stress on mixed stands, and particularly the beneficial rôle of beech in central European silviculture. He looks forward to the development of thinning practice along crown thinning lines. The second part deals with the division of the forest, mapping, forest capital, rotations, and the making of exploitation plans.

The publication appeared serially in the *Zeitschrift für Forst- und Jagdwesen*.

Les Châtaigniers Japonais au Sud-ouest Pyrénéen. By H. GAUSSEN. *Travaux du Laboratoire forestier de Toulouse*, article xvi, 1932.

LIKE the Oak Mildew, the Ink Disease of chestnut appears to have originated in Portugal, where it was noted in 1853, although it was probably present much earlier. It gradually spread eastward, and has been established in the French Basque country for some time. This paper presents the results of trials of resistant exotic species of chestnut, and although the primary purpose is not timber production, these are of some interest to British foresters, in view of the occurrence of Ink Disease in the south of England.

M. Prunet carried out investigations in France which established that the species *Castanea crenata* Sieb et Zucc. was resistant to Ink Disease. This species is a native of Japan and occurs in Korea and China also. Three varieties have been studied in France: *Siba gouri*, *Bon gouri*, and *Tamba* or *Tambu gouri*. From the point of view of the fruit,

the last is the best. The results of trials in different localities in south-west France are presented. Growth is fast, and fruit production is earlier than on the indigenous species. The climatic conditions of this region are substantially milder than even the south of England, and it remains to be seen whether the Japanese chestnut will be hardy here. It is worthy of note that in the south-west of France the buds begin to open at the end of February and the leaves remain on after the leaf-fall of the Common Chestnut.

Plans d'Aménagement des Forêts, volume 1. International Institute of Agriculture, Rome. 1932.

ONE of the resolutions passed at the International Congress of Silviculture, held at Rome in 1926, related to the collection and publication of official instructions for the preparation of working plans. This first volume of a series is the result and contains the instructions in force in Belgium, France, Hungary, Switzerland, and Quebec (Canada). The general form of presentation is to state the legislative enactments governing the management of forest, the instructions for the preparation of working plans, and to reproduce the forms used.

At present such information is very scattered, and not readily accessible, and when the information is completed in future volumes a useful work will have been done. It will stimulate the comparative study of methods of working plan compilation, and thus should lead to improvements in management.

La Milizia forestale nell'anno, IX. Rome.

THIS is a summary report on the work which Mussolini desired to be done for the protection and improvement of the forest and mountain lands of Italy, and which has been carried out during 1931 through the Forest Militia. It also refers to forestry and allied services which fall within the purview of the Ministry of Agriculture and Forests. The report deals with: Functions and organization of the Forestry Militia, protection of Italian forest lands, financial protection of forest and pasture lands belonging to communes or other public bodies, management of State-owned forests, improvement and development of forest culture. In 1931 approximately 20,000 acres were replanted. There are numerous illustrations of forest work, particularly reclamation work.

Pflanzen- und paläogeographische Mooruntersuchungen in N-Satakunta. Leo Aario, Fennia 55, No. 1, 1932, Helsinki.

THIS is a very thorough and complete investigation of a moorland. During the last few years a number of Scandinavian workers, among whom Auer and Malmström may be mentioned particularly, have substantially advanced knowledge regarding the origin and development of moorlands, and now comes an important contribution from Aario. The principal interest to workers outside Scandinavia is the methods of investigation employed. There are numerous illustrations, maps, and pollen diagrams.

The Use of Stumps (Root and Shoot Cuttings) in Artificial Regeneration. By H. G. CHAMPION and B. D. PANT. Indian Forest Records (Silviculture Series), vol. xvi, Pt. vi, 1932.

AUTHOR'S abstract: The stump method of planting out, pruning back nursery stock to a stem length of about $1\frac{1}{2}$ inches and root about 9 to 12 inches, has been gaining ground in India owing to the ease of handling and usually rapid growth. Avail-

able information is collected and investigations are described dealing with the influence of the variable factors affecting growth, such as dimensions, details of planting methods, storage, removal of surplus shoots, &c. The results of macroscopic examination of the regeneration of the root system are recorded. A search for rot consequent on the use of the method after four seasons' growth revealed no certain example. A summary by species is given, including 77 species.

Journal of the British Wood Preserving Association, vol. ii, 1932.

IN this volume the lectures delivered before the Association are printed together with the discussions which followed, and also other articles. The contributions include: 'The Structure of Wood', by L. Chalk; 'Diseases of Timber', by K. St. G. Cartwright; 'Recent Developments in Wood Preservation', by H. Fergusson; 'The Preservation of Mining Timber in the Witwatersrand', by H. A. Read; 'Experiments in Wood Preservation in the Sea', by J. H. Orton; and 'Wood Structure and Penetration of Preservatives', by F. J. Popham.

The Australian Forester, vol. iv, No. 1, Canberra, 1932.

THIS publication contains a number of interesting articles: 'Protection Forests', by B. V. Byles; '*Pinus radiata*', by G. W. Nunn; 'Private Afforestation Companies in Australia and New Zealand', by A. D. Lindsay; 'Notes on Forest Conditions in the Upper Murray Catchment in N.S.W.', by B. V. Byles; and 'Notes on the Wood-Gas Apparatus', by N. Cromer.

